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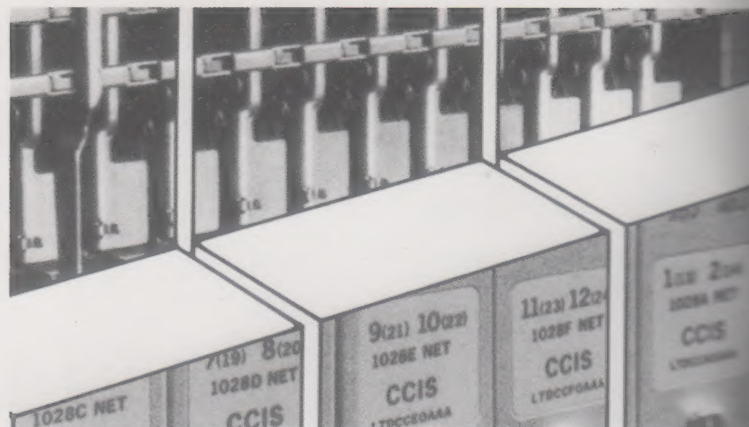

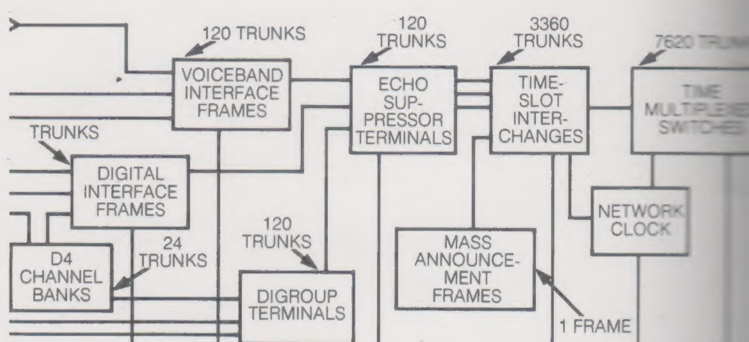

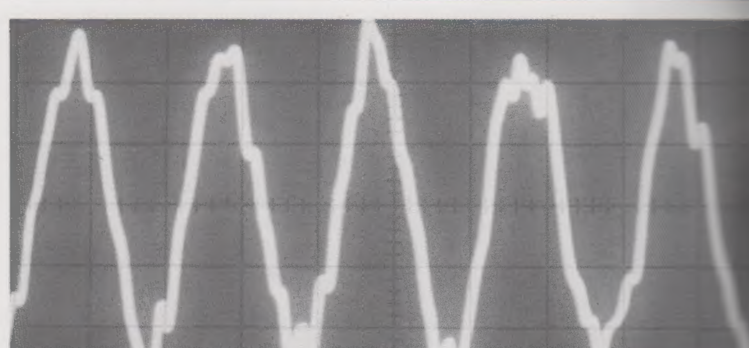

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DEPARTMENTS

Replacing electromechanical switching systems with No. 4 ESS is a key to modernizing the Bell System tandem network. Study guidelines and a computer-based system are helping Operating Company planners in metropolitan areas make sound economic decisions about replacement.

The No. 4 electronic switching system (ESS) was designed to provide service by economically handling less-than-maximum toll switching loads, and to grow to suit changing needs. Bell Labs develops and tests No. 4 ESS growth procedures that facilitate the addition of new equipment to already operational systems in order to support larger calling volumes, new features, and cost reductions.

Designing telephone systems that people want to use —and can use correctly—is a significant step in the development of efficient new services. One way to do this is to test customer reactions to different variations of a proposed service by simulating the service in an Operating Company environment. Automating the handling of current telephone credit card calling is an example of a potential service that Bell Labs tested in this way.

A programmable signal processor, developed for systems that analyze underwater sounds, can do 8 million calculations per second. This is far faster than most computers—and faster than any of its parts alone. The speed is achieved by design techniques that keep every part of the processor busy nearly all of the time. A unique design makes it adaptable to new applications at low software development cost.

About the cover—

The No. 4 electronic switching system (ESS) isn't really everywhere. It just seems that way. Throughout the Bell System, No. 4 ESS is helping modernize toll switching facilities. For a look at how No. 4 ESS systems are replacing electromechanical ones and how they are growing to handle increased traffic loads, see the stories on pages 138 and 146, respectively.

Tipping the scales for No. 4 ESS

The economies of replacing electromechanical tandem switching systems with the digital No. 4 ESS outweigh the capital costs. The proof is in the planning study.

Bruce H. Fetz and Pamela M. Moricz

At a time when the decreasing costs of electronics literally defy inflation, more and more Operating Companies are finding it economical to replace electromechanical tandem switching systems with electronic ones.

Nowhere is that more apparent than in metropolitan areas, where No. 4 electronic switching systems (No. 4 ESS) not only have lowered costs, but also have increased productivity and improved flexibility for tandem switching offices.

Tandem switching systems connect trunks to trunks. They include what have traditionally been called toll switching systems (for long-distance traffic) and local tandem systems (for local traffic within a large metropolitan area).

The electromechanical No. 4 crossbar and crossbar tandem switching systems, both of which were introduced in the 1940s, have been the mainstays of the Bell System's long-distance network for many years. But growth in metropolitan area toll traffic, anticipated requirements for expanded services, and the need to reduce operating expenses demanded a high-capacity switching system that was modular, flexible, and economical.

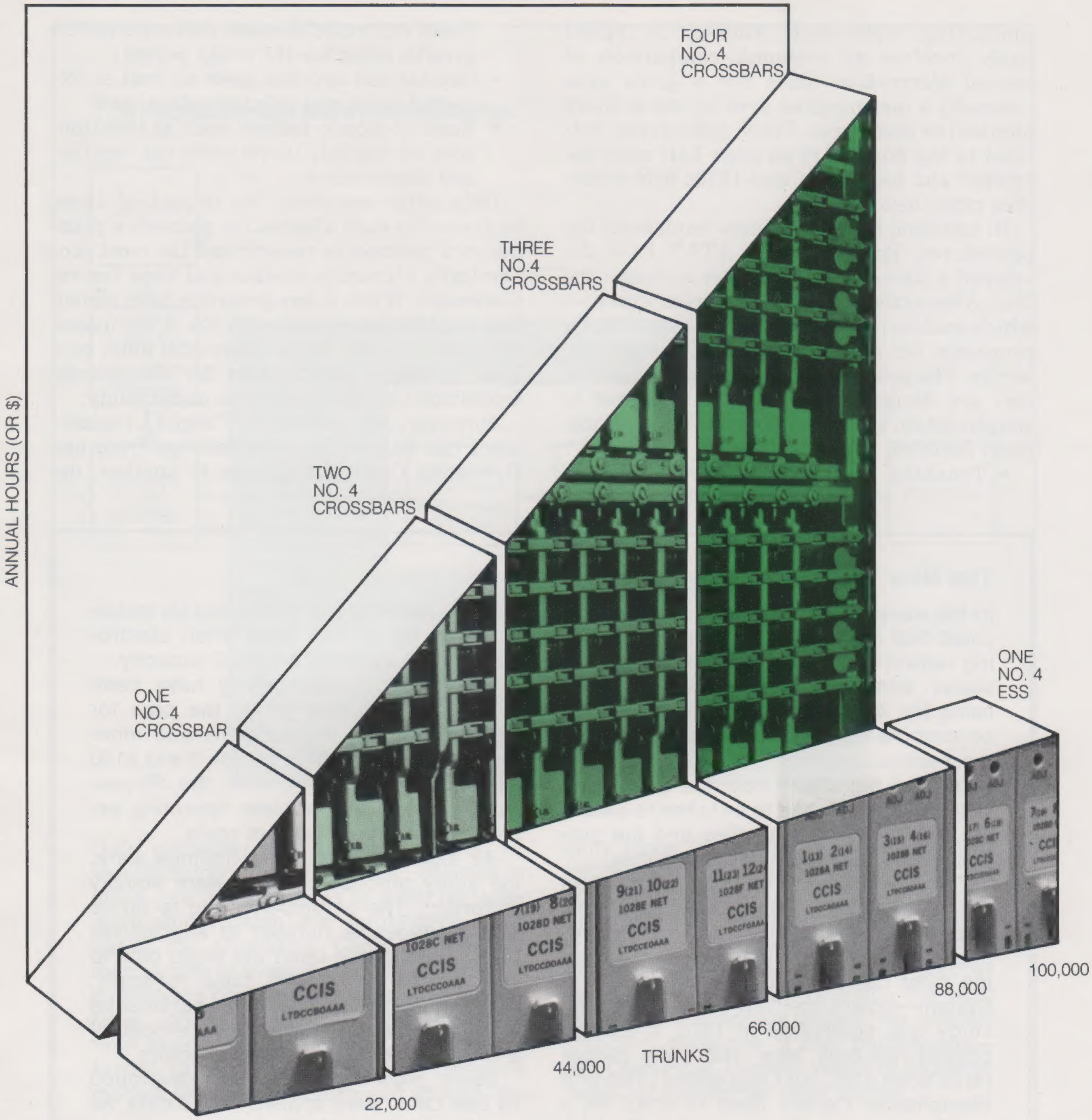
That demand is being met by No. 4 ESS—with its ability to process over one-half a million calls an hour and accommodate more than 100,000 trunks; with its modern integrated circuitry and digital capabilities; with its ability to provide new features with changes in software; and with its reduced space and power requirements. The system "grows," in terms of call-handling capacity and features, through increases in memory capacity, expansion of the office data base, and the addition of peripheral equipment. (See *No. 4 ESS growth: serving increased toll switching needs*, page 146.)

Electronic switching also makes possible the Bell System's Stored Program Controlled Network. When stored program control is combined with Common Channel Interoffice Signaling, and when selected data bases are added to the network, a number of new customer services become feasible. These include automated billing services now requiring operator assistance, improved INWATS (toll-free "800" calling), and selective ringing. (See *Realizing the potential of the stored program controlled network*, RECORD, February 1979.)

So with conversion to electronic switching systems offering such benefits, it is not surprising that since the introduction of No. 4 ESS in January 1976, it has been replacing electromechanical No. 4 crossbar and crossbar tandem switching systems at a pace that shows no signs of slowing down.

From a peak of 182 No. 4 crossbar systems in service in June 1976, there are expected to be only about 111 left by the end of this year. An additional 31 No. 4 crossbar systems are scheduled for replacement in 1981.

In comparison, at the end of March, the Bell System had 36 No. 4 ESS systems in operation, and there are expected to be 53 by the end of



Operating Expenses. A single No. 4 ESS offers lower operating expenses than one No. 4 crossbar system for comparable trunk volumes. In addition, the difference in total operating costs continues to grow, as additional electromechanical systems must be added to achieve the same trunk capacity as one No. 4 ESS.

1980. At that time, these systems will terminate roughly 1.7 million trunks, over one-third of the total Bell System terminations.

In view of these trends, No. 4 ESS emerges as a generally sound economic alternative for modernization in areas with a large traffic demand. Therefore, questions facing Operating Company planners are when to install No. 4 ESS—as soon as possible or not until existing electromechanical systems reach capacity—and when to replace the existing systems.

To help Operating Company planners find the answers, Bell Labs and AT&T developed comprehensive procedures and guidelines for

conducting replacement studies. A typical study involves an economic comparison of several alternative plans for a given area—usually a metropolitan area or one or more numbering plan areas. These procedures, outlined in the flow chart on page 141, were developed and tested in a mid-1970s field study. (See panel below.)

In addition, to help planners implement the procedures, Bell Labs and AT&T have developed a time-shared computer system—the Toll Alternatives Studies Program (TASP)—which enables planners to evaluate more easily proposals for alternative toll switching networks. The procedures and the computer system are designed to enable the planner to weigh certain key factors in making a replacement decision. These include:

- Trunking and switching requirements based on traffic demand and anticipated growth rates for the study period;
- Capital and expense costs as well as expected reuse and salvage values; and
- Basic economic factors such as inflation, cost of capital, investment tax credits, and depreciation.

Only after weighing the impact of these factors—for each alternative plan—is a planner in a position to recommend the most economically attractive system and time for replacement. While it has *generally* been shown that rapid replacement with No. 4 ESS makes the best economic sense, there still must be a clear economic justification for the *specific* Operating Company and area under study.

However, the concept of "rapid" replacement can have different meanings from one Operating Company or area to another, de-

The New York experience

In the early 1970s, Bell Labs studies indicated that replacement of tandem switching networks with No. 4 ESS could be a sound economic alternative to merely using No. 4 ESS to accommodate growth beyond the capacities of existing electromechanical systems.

But the big step—from the theoretical to the practical—had to be taken to assure the validity of these studies and the proposed Bell Labs planning guidelines.

That step came in the mid 1970s, when Bell Labs, AT&T, Long Lines, and New York Telephone decided to test and refine available study methods in perhaps the most complex study area in the Bell System—downstate New York. Before the study was completed in 1976, it encompassed not only New York City proper (area code 212), but Long Island (516) and Westchester County (part of 914). As a result, it became known as the Tri-NPA Study.

At the time of the study, the Tri-NPA region had 56 crossbar tandem switching systems and 11 No. 4 crossbar systems. The systems handled long-distance interstate traffic, intrastate toll traffic, and local tandem traffic.

Using two existing network engineering programs as a starting point, the studies considered alternatives for earliest possible installation of No. 4 ESS, and for installation of No. 4 ESS only when electromechanical systems reached capacity.

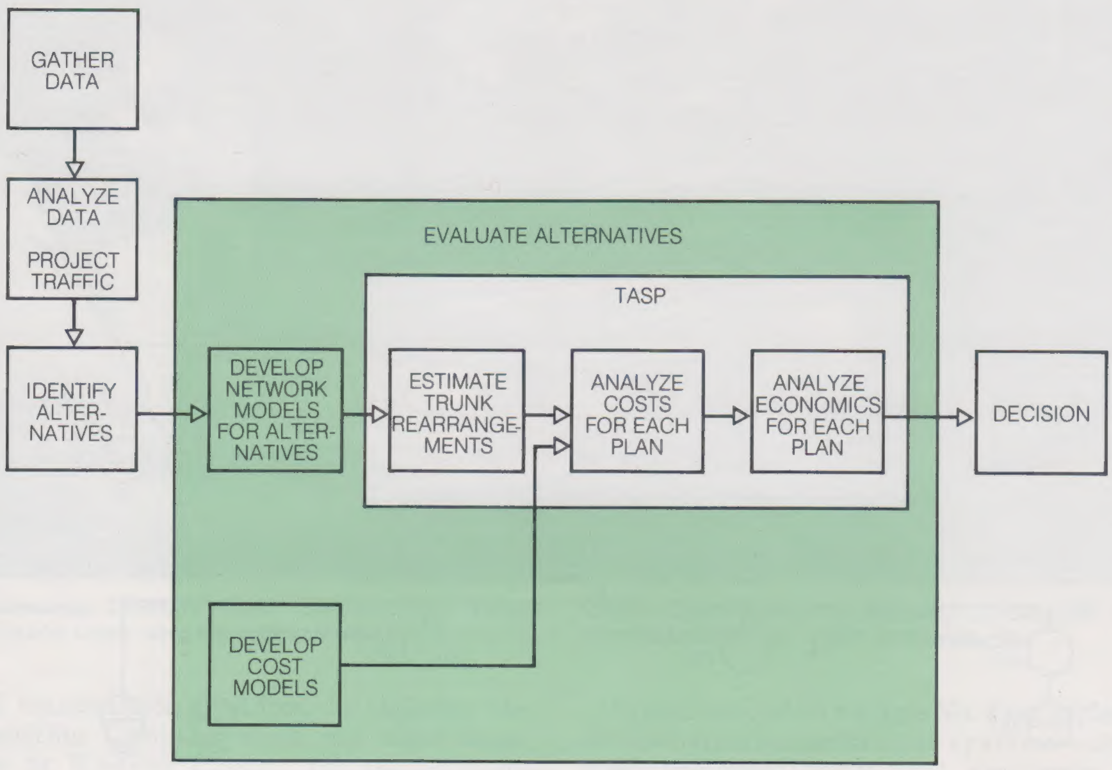
The results of that study have been echoed many times. While the plan for earliest possible replacement was more expensive in terms of first cost, it was $100 million less expensive, over the 20-year study period, due to lower operating expenses and rearrangement costs.

As significant as those findings were, the study procedures used were equally important. The participants had to arrive at a manageable number of alternatives to evaluate, agree upon the basic data to use, decide on growth rates to apply, settle on the financial and cost parameters to consider, and develop new methods of analysis to address emerging factors.

Basic planning guidelines, developed by Bell Labs, were applied to real data. As problems emerged, the guidelines were modified or new ones were developed. The result was not only an economical plan for the modernization of the downstate New York network, but a detailed methodology with far-reaching effects.

The groundwork had been laid for a still-evolving planning system—which now includes the Toll Alternatives Studies Program (TASP)—to help ensure properly timed and profitable network changes.

Toll replacement study procedures



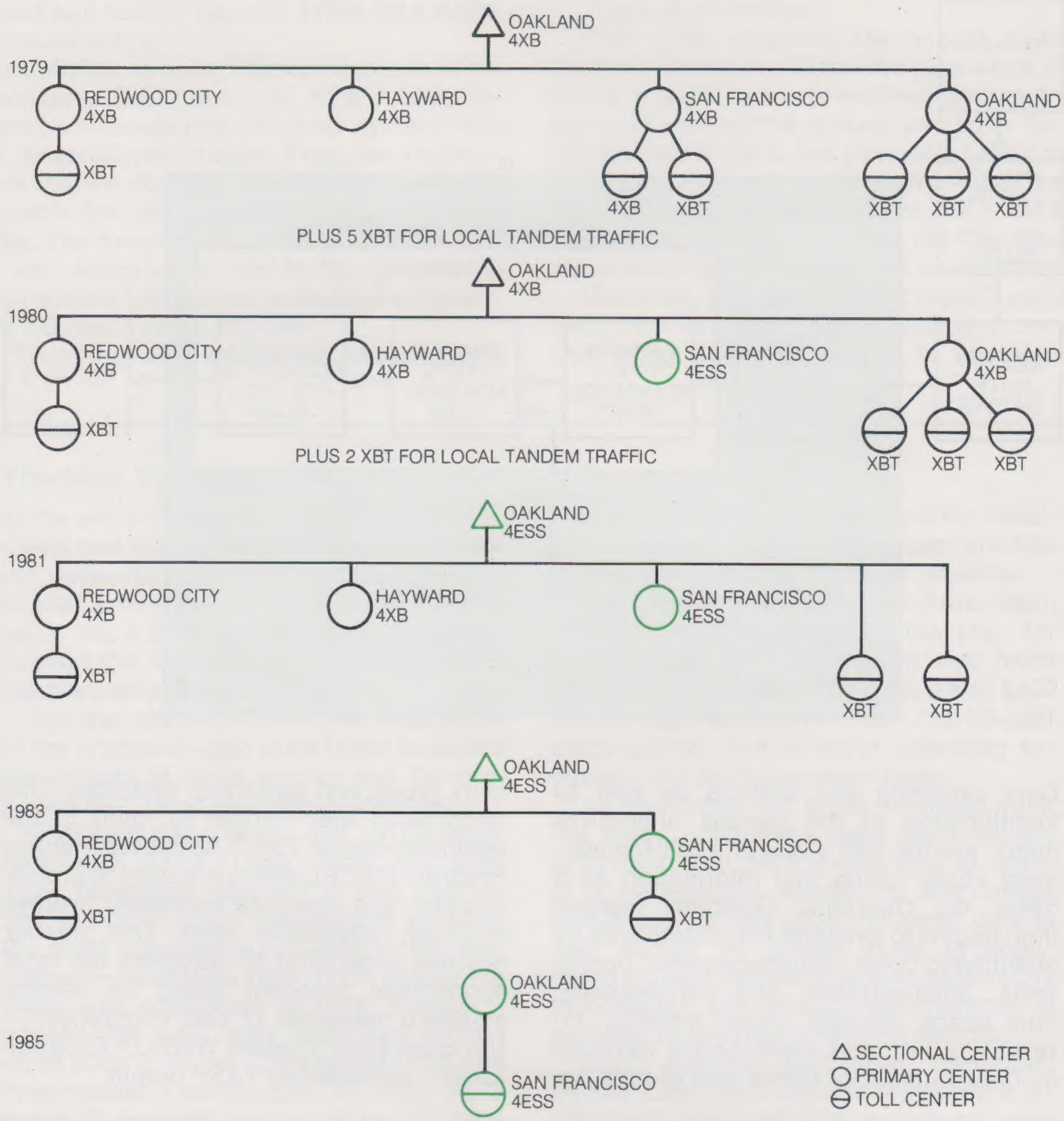
Data gathering and analysis, as well as identification of the various alternative plans, are the first steps in a toll replacement study. Using that information as a basis, the Operating Company planner then begins to evaluate the alternatives by quantifying costs (rearrangements; operations, administration, and maintenance; floor space; salvage values; inflation; interest rates) and developing network models (number of trunks and groups, facility types, and switching systems). This information then serves as input to the computer-based Toll Alternatives Studies Program (TASP), where it is used to create, analyze, and compare economic profiles for each alternative plan. The planner reaches a decision by selecting the most economical proposal based on several standard measures of cost comparison—Net Cash Flow, Present Worth of Expenditures— provided as TASP output.

pending upon the differing availability of resources and needs. Expected growth rates, the availability of capital and craftspersons, and plans for the cutover of other equipment can all contribute to making even "rapid" replacement a clearly evolutionary process. The Oakland/San Francisco area replacement plan, requiring six years, is an example. (See panel on page 142.)

Now let's follow the process as a planner examines some of the factors and tradeoffs that are part of every No. 4 ESS replacement study. As in most such studies, the dominant tradeoff concerns the substantial initial capital expenditures for No. 4 ESS, versus the subsequent operations, administration, and maintenance savings.

Among the first costs for No. 4 ESS replacement are equipment purchases, as well as installation and testing of the switching system

Evolutionary replacement



The replacement with No. 4 ESS of the existing No. 4 crossbar (4XB) and crossbar tandem (XBT) switching offices in the San Francisco/Oakland area is expected to require six years. Beginning with a No. 4 ESS at the San Francisco primary center in 1980, the area will rely on fewer electromechanical switching systems each year. As cost and labor constraints permit, new high-capacity No. 4 ESS systems will be added, allowing the area's switching system hierarchy to evolve toward the simple configuration shown for 1985. At that time, the call-switching needs of this major metropolitan area, and several surrounding suburbs, will be served entirely by a No. 4 ESS primary center in Oakland and a No. 4 ESS toll center in San Francisco.

Maintenance. Theodora Hamer, communications technician, Long Lines, uses the maintenance control console to more easily monitor the equipment performance of a recently installed No. 4 ESS in Newark, N. J.

and transmission facilities. In addition, the Operating Company must pay right-to-use fees to Western Electric for the software needed to operate the system.

However, long-term expense savings with No. 4 ESS often outweigh those early investments. Some areas of savings include:

- Less routine maintenance required for ESS equipment than for electromechanical;
- Mechanized procedures for routine diagnostic tests to help increase the efficiency of craftspersons;
- Data retrieval capability to eliminate most paper records; and
- The use of centralized work centers to handle several No. 4 ESS offices.

As a result of these features, lower overall operating expenses for the No. 4 ESS are possible. (See illustration on page 139.)

If the No. 4 ESS is installed in a different location from the electromechanical system it replaces, transmission facilities may have to be changed or extended. Traffic might have to be routed over different facilities. Again, these are part of the first costs. But this gives Operating Companies the opportunity to modernize by replacing existing analog trunks with lower-cost digital facilities.

In addition, when a single No. 4 ESS replaces several electromechanical systems—as is often the case—traffic that previously required trunk groups from each system can be combined on one trunk group. This can mean significant savings in transmission facilities with No. 4 ESS because of the increased efficiency of larger trunk groups and the reduced need for trunk groups between tandem offices.

Among the benefits of No. 4 ESS are also lower power requirements for both switching and transmission equipment. For example, in a major metropolitan area, a comparative study of power required to run switching and transmission equipment showed that No. 4 crossbar and crossbar tandem offices each required roughly 20 percent more watts per termination than a No. 4 ESS office as originally designed. Subsequent improvements in the No. 4 ESS design have further reduced power requirements to less than one-third those of the No. 4 crossbar office.

Rearrangements

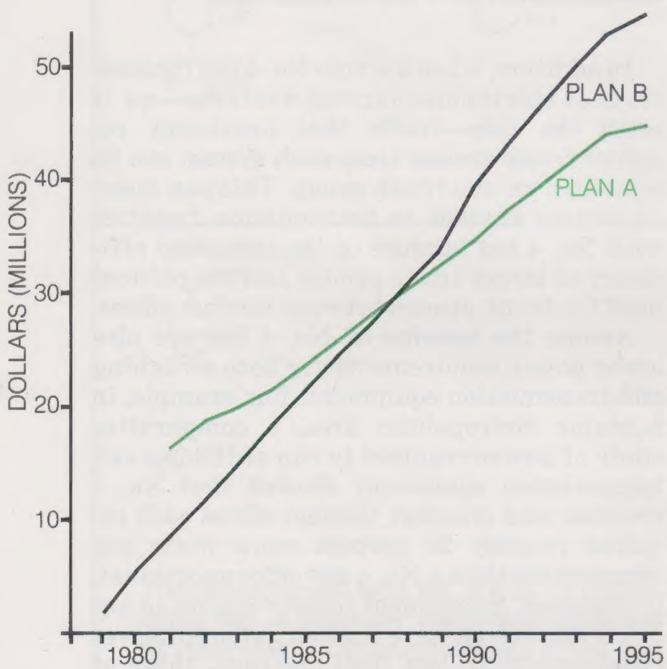
Whenever a tandem switching system is replaced, trunks from the old system or transmission facility must be disconnected, moved, and reconnected to the new one. The one-time

costs for these activities include engineering, recordkeeping, printing and mailing costs in producing a circuit order, as well as costs in processing the trunk order, wiring, testing, and sending completion notices to the appropriate organization.

In contrast to electromechanical systems, where extensive handwiring is needed to connect each frame to many other units, rearrangements with No. 4 ESS are quicker, simpler, and less costly. Some reasons for this are: the integrated modular design of toll terminals and switching equipment; multiplexing to reduce the number of interframe connectors; and the use of precut, plug-in cable.

In replacement studies, significant factors can be the cost of floor space for the new switching office and the reuse value of floor space vacated. The vacated space can be used to expand other facilities or to defer or cancel new building construction.

No. 4 ESS, with its modern circuitry and digital equipment, requires much less floor space than an equivalent No. 4 crossbar system serving 10-20,000 trunks. In addition, as the need for trunking capacity grows beyond



Net Cash Flow. This chart shows the negative of the discounted cumulative Net Cash Flow for Plan A: a No. 4 ESS installed in 1981 (1982 service); and Plan B: retention of a No. 4 crossbar and a crossbar tandem system until capacity, then adding a No. 4 ESS for growth in 1990 (1991 service). No. 4 ESS lower operating expenses begin to offset initial capital expenses in 1982 and, by 1988, make Plan A less costly.

the limits of a single electromechanical system, the floor space savings attributable to the larger-capacity No. 4 ESS become even greater.

A comparative study of floor space requirements in terms of trunking capacity showed that No. 4 crossbar and crossbar tandem offices require at least four times more square feet per termination than a No. 4 ESS office as originally designed. And with the increased use of integrated circuits and new frame designs, still greater savings in floor space required for the switching network and digital and analog terminals are possible. The most recent No. 4 ESS design requires less than one-sixth the floor space of a comparable electromechanical office.

Replacement also requires a decision about the existing transmission facilities. Some existing analog terminal equipment can be modified to interface with No. 4 ESS, or it can be used as is. If new terminal equipment is purchased, the cost impact of that new equipment may be somewhat lessened by reusing the old terminal equipment for private lines or for growth elsewhere in the system. Similarly, the salvage value of replaced switching equipment, and the related removal costs, must be considered in the overall cost analysis.

Reaching a decision

These are just some of the major cost factors the planner identifies for each alternative. The planner assigns dollar values to such factors as operations, administration, and maintenance; switching equipment; transmission facilities; and floor space. The planner then applies such economic parameters as inflation rates, tax rates, and cost of capital. Using these dollar values, the planner next creates an economic profile for each plan under consideration.

Once the profiles have been developed, the next step is to analyze and compare them, and select the most economical one. The creation, analysis, and comparison of the profiles is the primary function of the time-shared TASP system. (See panel on page 145.)

The methods of cost comparison include Present Worth of Expenditures (PWE) and Net Cash Flow. The PWE technique determines the present worth, at a given discount rate (cost of money), of all expenditures for each proposal for the length of the study period. The difference in the PWE of two alternatives shows the potential savings that can be attributed to the one with the lower PWE.

Smoothing the way with TASP

Since late 1976, Operating Company planners have been able to use the computer-based Toll Alternatives Studies Program (TASP) to analyze proposed alternative tandem replacement plans. TASP allows the planner to conduct long-range studies with fast turnaround, quickly dismiss uneconomical alternatives, and gauge the timing of replacement.

A generalized switching model provides the planner with enough flexibility to answer most of the questions associated with switching network studies. The model can use—but does not require—detailed trunk engineering of the network.

The planner provides an initial description of the network—in terms of switching systems and the number of working circuits by facility type—for each alternative, and specifies how the network is to evolve over the study period. Other required input includes trunking information and growth rates, schedules for planned retirements and new installations of switching systems, and strategies for accommodating growth by rehoming end offices to other systems. In addition, economic parameters such as financial and tax data, unit costs for new equipment, salvage values for vacated equipment, and inflation factors are entered.

After TASP uses this information to estimate capital and expense dollars for the proposed plans, it computes the economic indicators necessary for evaluation. One TASP run can compute costs and economic indicators for a single alternative or for two proposals.

Among the specific results that TASP calculates are first costs; reuse and salvage values; operations, administration and maintenance expenses; revenue requirements and Net Cash Flow on a year-by-year basis, as well as Present Worth of Expenditures.

And just like the No. 4 ESS itself, TASP continues to evolve in response to user needs. Most recently, the program was modified to incorporate the Capital Utilization Criteria (CUCRIT), the Bell System standard economic analysis tool. This change not only will ensure that TASP output is expressed in a format most commonly known to Bell System management, but also will readily implement any changes in tax laws, policies and procedures as part of AT&T's continuous updating of CUCRIT.

The planner must recognize, however, that there may be certain constraints unique to the Operating Company. For that reason, one of the most descriptive and meaningful interpretations of the data is the yearly discounted Net Cash Flow. Net Cash Flow for any one year of the study is the total revenue plus net salvage value less all expenses, taxes, and first costs. It is an after-tax cash flow. By expressing capital expenditures, operating expenses, and discounted cumulative Net Cash Flow for each year, the study results can show both cost differences between plans and the critical year in which the tradeoff value of lower expenses becomes a positive factor.

Thus, discounted cumulative Net Cash Flow and PWE are equivalent measures that complement each other and allow the planner to give full consideration to capital and labor constraints that eventually dictate replacement timing.

The computer-based TASP system, developed by Bell Labs, not only mechanizes and greatly simplifies the computation and comparison of the PWE and Net Cash Flow data, but plays a prominent role in the final decision.

AT&T's No. 4 ESS Deployment Committee requires that Operating Companies planning to purchase No. 4 ESS equipment for replacement submit TASP studies, which compare their proposal with several alternative plans. The committee uses the results of the TASP studies to balance Western Electric production levels with demand for No. 4 ESS equipment. The most economical applications—based on study results—are given priority.

In the final analysis, these hard looks at the economics of tandem switching network replacement not only point the way toward the most effective system possible but, just as important, show how and when that system can profitably become a reality. □

Recent changes. At the Indian Hill No. 4 ESS System Lab, William Myrick enters recent change messages into a No. 4 ESS central processor. These messages control new equipment as it is being added to the No. 4 ESS.

No. 4 ESS growth: serving increased toll switching needs

Two-thirds of all operational No. 4 ESS systems have been expanded to handle greater traffic loads since their initial cutovers.

EDWARD A. DAVIS

The No. 4 ESS is often described in terms of its impressive maximum capacity: It can switch over a half-million toll calls an hour, and can terminate a hundred thousand trunks. But Bell Labs designed the "super switcher" to serve more modest toll switching needs economically, and to grow to full size in incremental steps.

A No. 4 ESS "grows" when it becomes capable of handling more calls and providing additional features. Growth is accomplished by increasing the capacity of the No. 4 ESS memory, expanding the office data base, and adding peripheral equipment to the system. With the help of growth procedures designed by Bell Labs, existing No. 4 ESS systems across the country are growing rapidly to provide for rising long-distance calling volumes, and to continue the replacement of older No. 4 crossbar toll switching systems. (See *Tipping the scales for No. 4 ESS*, page 138.)

Maintaining uninterrupted service is a primary consideration in designing growth procedures. But growth must also be efficient and easily managed. From the start, Bell Labs designed the No. 4 ESS with growth in mind, guided largely by analysis of earlier electronic switching systems.

The results of these studies showed that a "test only" state was needed so that normal system diagnostic tests could be run safely on equipment to be added. This testing capability for growth equipment was built into the No. 4 ESS generic program. In earlier systems, a separate set of auxiliary programs was needed for growth-unit testing, in order to avoid disturbing the operation of the system.

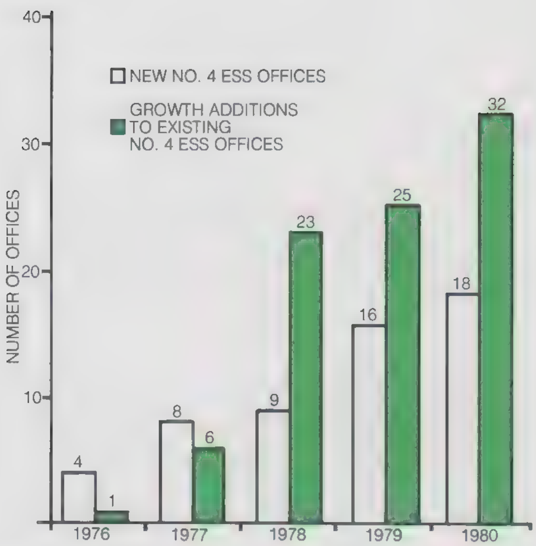
Bell Labs engineers also found that Operating Company technicians needed a system to allow quick and accurate administration of the growth process, and to guide new equipment through stages of growth testing. This capability was built into the No. 4 ESS data base administration system (see *Data base administration: managing the giant*, RECORD, December 1977).

Scheduling growth

Before an Operating Company schedules expansion of a No. 4 ESS, planning engineers forecast office requirements for a number of years into the future. The forecasts predict traffic loads the system will have to handle, and the number and types of trunk terminations and service features needed to meet customer demands.

Once engineers have estimated these requirements, they schedule equipment growth to make increased capacity or new features available when they are needed. Other important considerations in setting timetables are Western Electric's equipment production and data base generation capacities.

The Operating Company prepares information used by Western Electric's Switching Software Center in Lisle, Ill., to compile a new Office Data Assembly, or ODA. The ODA is a customized data base that is stored in the No. 4 ESS central processor Call Store memory. A backup copy is also kept in the File Store memory. The ODA describes the equipment and configuration of the particular



Growth trends. No. 4 crossbar toll switching systems are being replaced by new No. 4 ESS systems and by large growth additions to already-existing No. 4 ESS systems. Growth additions are also the result of an increasing volume of long-distance calling.

switching system. The ODA information, known as translations data, tells the central processor what facilities are part of the switching system and can be used to handle calls. Operating Company technicians manipulate the translations data to control the growth process.

The introduction of growth equipment requires that additional information be included in the new ODA. Not only does the new ODA contain translations data describing the existing system and growth equipment for immediate needs, but it also describes equipment that can handle needs beyond the scheduled growth job. This provides flexibility. If there is an unforeseen surge in demand, the ODA will be able to accommodate extra No. 4 ESS growth. In order to hold the expanded translations data provided by the ODA, the No. 4 ESS memory capacity may have to be expanded by using memory growth procedures before peripheral equipment growth activity can proceed.

Bell Labs usually introduces an updated generic program each year to add new service features and new maintenance and administrative features to the No. 4 ESS. For convenience, Operating Companies generally introduce the new growth ODA at the time of the annual generic retrofit.

Extensive factory tests help ensure that the growth equipment is shipped in proper operating condition. Standardized floor plans reduce the complexity of the office-engineering effort associated with growth, and factory-connectorized cables allow rapid installation of the equipment. The modular design of the No. 4 ESS central processor and peripheral equipment permits growth by increments of either full equipment frames or subunits of a frame, depending on the needs of the Operating Company and the design of each type of equipment.

Generally, No. 4 ESS growth proceeds from the inside out. This means that the processor memory capacity is increased first. Then frames are added to the time-division switching network, which consists of the Time-Multiplexed Switch frames and the Time-Slot Interchange frames (see *Switching and signal handling*, RECORD, December 1977). Other equipment is added in sequence, working from the time-division switching network toward the analog and digital transmission interface equipment. Finally, the Operating Company can activate and test additional trunk circuits as demand requires.

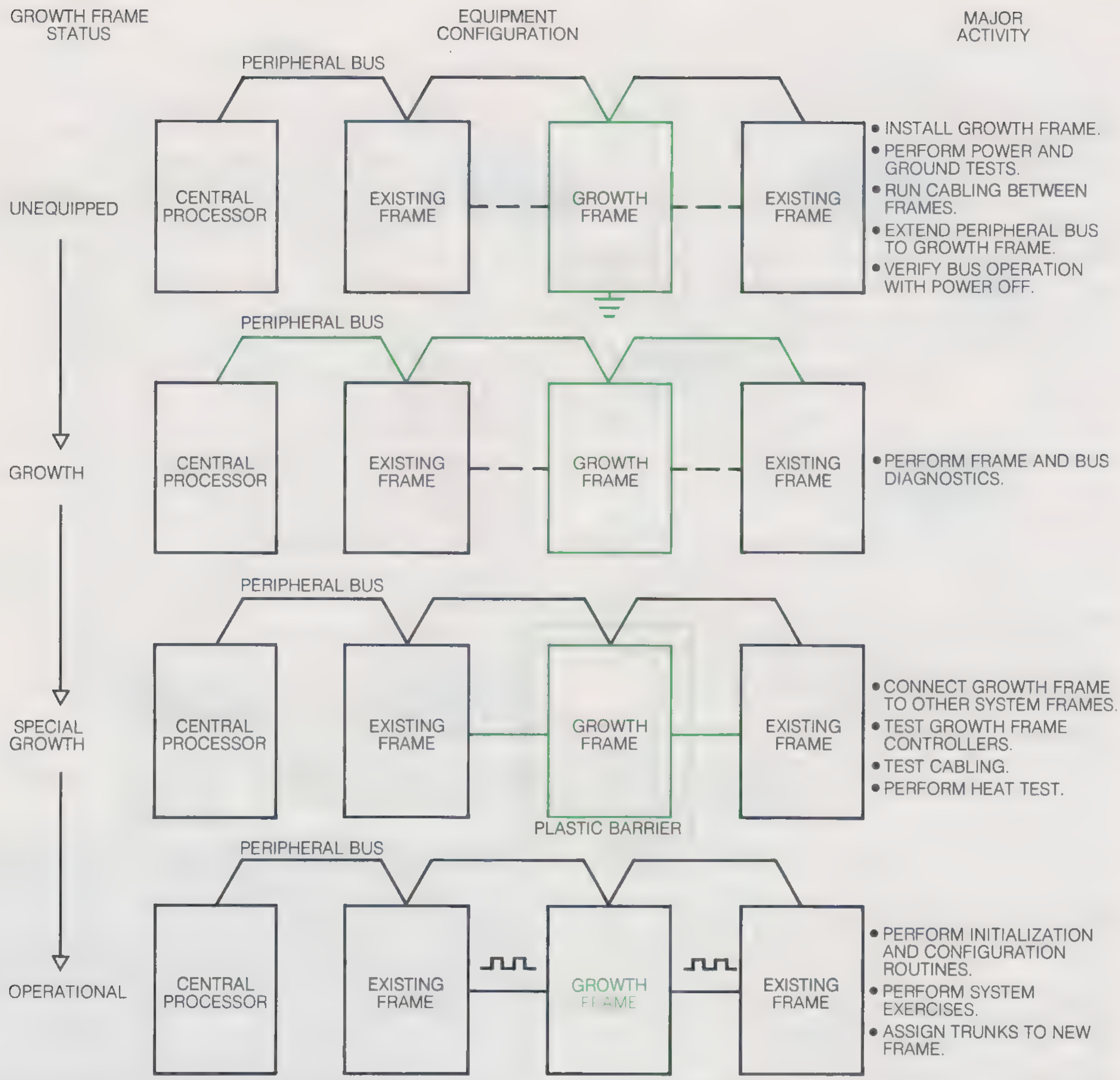
Efficient No. 4 ESS growth depends on the cooperation of several Bell System groups. Operating Company craftspersons and managers play a major role. In addition, Western Electric provides customer services, regional engineering and installation services, and a product engineering support organization. Help also comes from the national No. 4 ESS Switching Assistance Center, which is staffed by Long Lines and Operating Company personnel. Bell Labs No. 4 ESS field support people interact with all these groups.

New methods

Growth procedures developed by Bell Labs guide the introduction of new No. 4 ESS equipment. Bell Labs engineers design and test the procedures at the No. 4 ESS System Lab at Bell Labs, Naperville, Ill.

The procedures are tested again at a new No. 4 ESS office that is about to be cut into service for the first time. In an Operating Company environment, Bell Labs checks out and "debugs" the new methods before they become standard for application to operational No. 4 ESS systems.

Documentation design proceeds hand-in-hand with development and testing of the growth procedures. Bell System Practices and Task Oriented Procedures give Operating Company managers and craftspersons such



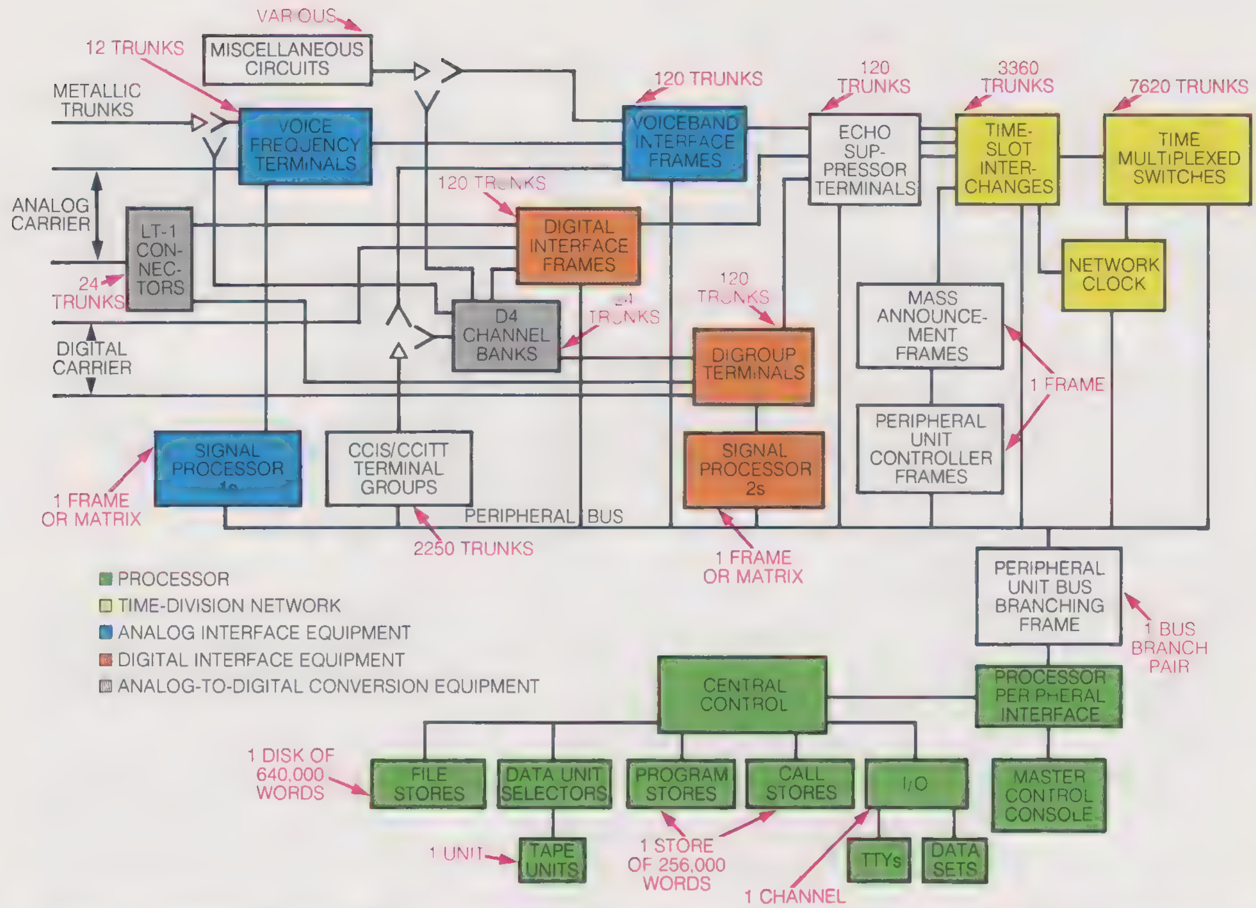
Stepwise growth. No. 4 ESS equipment "grows" in steps, according to the growth equipment status recorded in the translations data. The growth process outlined here may vary, depending on the kind of equipment involved.

information as an overview of the growth process, checklists of growth steps, and detailed instructions for implementing each step, as well as various system tests and verification tools. The standard issues of this documentation are produced by the Western Electric Data Design Organization. A Western Electric growth installation handbook complements the Bell System Practices and Task Oriented Procedures by explaining the responsibilities of Western Electric installers.

The Task Oriented Procedures and the Western Electric growth installation handbook are used by Operating Company technicians and installers to perform trial growth testing in test offices before cutover. This way, feedback on the documents can be incorporated prior to their being issued.

Even though each kind of No. 4 ESS equipment has a unique growth procedure, there are many similarities among the methods used to bring growth equipment on-line.

Equipment growth is administered primarily by recent change messages and verify messages entered into the translations data base from a *DATASPEED*® 40 terminal. These messages are "read" by the recent change and verify subsystems of the data base administration system, which modifies the translations data. In addition to providing control over the state of growth equipment, recent change and verify messages are routinely used



Growth increments. This diagram shows typical growth increments (in red) for the major No. 4 ESS units and subunits. The modular design of the No. 4 ESS permits expansion of almost every kind of system equipment.

by the Operating Companies to make day-to-day rearrangements of call routing patterns, and trunk reassignments.

Formatted display screens list descriptive information about each piece of growth equipment. A recent change message allows all translations changes associated with growth to be implemented using standard functional messages. Verify messages are used to request checks on the accuracy of all recent changes. To do this, the verify subsystem examines the changes for logic, consistency, and format. Since an error in the translations data could degrade service, the subsystem notifies the user and suggests a corrective action if improper data have been specified.

At the start of the growth process, all translations data are checked, and Operating Company technicians verify that each growth frame is marked "unequipped." This ensures that the central processor knows that it should ignore the growth equipment when handling calls or performing fault-recovery actions.

With the growth equipment marked "unequipped" in the translations data, the new equipment frames are secured in their assigned positions. Then installers check equipment power and ground connections and place the cabling that will later connect growth equipment to the operational frames. Installers extend the peripheral bus to the growth frames. The peripheral bus is the communication link between major No. 4 ESS equipment and the central processor; it is duplicated for reliability. Bus operation is checked with the power to the frame turned off.

One at a time, each of the two peripheral buses is taken out of service and installers connect the growth frame to the out-of-service peripheral bus. Using an oscilloscope, they observe a digital-stream test pattern as it travels along the out-of-service peripheral bus to the growth frames. This test makes sure the growth frames can communicate properly

with the central processor.

The second major step in the growth process is the stand-alone testing phase. Terminal operators change the translations designation of the growth frames from "unequipped" to "growth." Then scan and signal distributor points on each frame are connected. A scanning program monitors scan points to tell the central processor the state of the control switches on the growth frames. The central processor uses the signal distributor points to acknowledge the actions of technicians at the growth-frame control switches. Next, installers conduct frame and bus diagnostic tests by calling up diagnostic routines that are part of the generic program.

For the third step in the growth process, installers connect the cables that will carry time-division multiplexed digital samples of telephone conversations between the growth frames and the already-operational frames. Terminal operators enter recent change messages to mark the growth-frame translations with the "special growth" indicator.

In the special growth state, diagnostic tests check the interequipment cabling. Additional tests verify the operation of the frame controllers. The duplicated controllers receive orders from the ESS central processor, ensure that the orders are carried out by the equipment, and report completion back to the central processor. In this state, special controller "matching tests" are run on the duplicated controllers to ensure they react properly to commands from the central processor.

During this growth phase, new equipment that hasn't been heat-tested before shipment from the factory is enclosed in a plastic barrier and heated. This process helps identify marginal components so that they can be replaced before the equipment goes on-line.

Diagnostics. Eric Ploom, Bell Labs, uses an oscilloscope to monitor the signal on a No. 4 ESS Program Store bus. This is part of one test that verifies the No. 4 ESS central processor growth procedures under development.

The operational state

Growth equipment is placed in service in the last step. Recent change messages advance equipment to the "operational" state. In this way, the central processor learns that the new equipment is available for service and is to be treated like any other operational frame by the system maintenance programs. Initialization and configuration routines prepare growth frames so new equipment can begin to work as part of the system without adversely affecting service. As growth frames become operational, recent change messages are used to assign trunks to new equipment.

So far, two-thirds of the operational No. 4 ESS systems have undergone growth. Through the end of 1979, growth activity has added more than 900 frames of No. 4 ESS equipment, providing for over 350,000 new trunk terminations. This is equal to nearly one-third of all No. 4 ESS terminations. Some offices have already been expanded several times. One office has twice doubled in size, and another office will soon be enlarged to quadruple its present capacity.

Bell Labs continues to develop new procedures to help introduce the equipment that supports new features, cost reductions, and switching technologies. Along with the new procedures come enhanced testing methods and tools.

The ability to "grow" No. 4 ESS systems efficiently adds to the super switcher's flexibility, allowing Operating Companies to install the systems to handle less-than-full traffic volumes, and to defer purchase of substantial amounts of equipment until it is needed. The system growth capability also allows Operating Companies to introduce the latest equipment and services in early-vintage No. 4 ESS offices, ensuring the most efficient and modern long-distance telecommunications services are available to Bell System customers. □

Bell Labs marks 30th anniversary of computer error-correcting codes

It was simple human frustration that led Dr. Richard W. Hamming, then a research mathematician at Bell Laboratories, to devise the first method for correcting machine-caused errors in digital computers.

Hamming's technique—which was a result of his research in pure mathematics—enabled computers to spot electrical errors in the data and instructions and tell where they occurred. And, for the first time, it enabled computers to correct those errors and go right on solving problems without interruption.

April 20, 1980, marks the 30th anniversary of Hamming's pioneering work, which has evolved into a new field of research called error-correcting codes. Besides aiding the computer industry, error-correcting codes are also essential to call-processing accuracy in the Bell System's No. 1 ESS (electronic

Thirty years ago, at switchboard of apparatus that enabled computing machines to correct their own mistakes, are Richard Hamming (left) and Bernard Holbrook, under whose direction the apparatus was built.

switching system).

Hamming's frustration came about because early computers would simply stop operating whenever they detected an error.

"I knew that if the computer was smart enough to detect an error and shut itself off to prevent false answers to the problem, then it could be made smart enough to correct that error and continue computing," Hamming recalls.

In time, Hamming devised a method using a combination of several odd-even checks to identify precisely the position of the error and make the correction. Apparatus incorporating Hamming's mathematical discovery was constructed under the direction of Bernard D. Holbrook, then a Bell Labs switching research engineer.

In the early days of computers, errors usually were caused by faulty relay contacts, open circuits, false grounds, or disturbances induced by outside sources. Today, even with the advent of solid-state components, extraneous signals still find their way into the individual transistors and other electronic devices to cause potential errors.

The error-detecting and -correcting capabilities of Hamming's codes are provided as part of the processor hardware of the Bell System's No. 1 ESS. At year-end 1979, there were more than 900 such systems across the country serving almost 19 million customer lines. Hamming codes are also used in Bell System electronic tandem switches and in electronic long-distance operator consoles.

One Bell Labs engineer recalls the effectiveness of Hamming's codes demonstrated during the 1960 trial at Morris, Ill., of the world's first ESS. A small piece of wire fell across two terminals of one program memory while the duplicate memory was out of service. This resulted in the possibility of 33,000 call-processing mistakes per second. It took Bell maintenance personnel nearly an hour to find the tiny wire. However, not a single call was misdirected because Hamming's codes automatically corrected each of the thousands of errors the machines made each second.

Hamming joined Bell Labs in 1946, specializing in the use of numerical methods for solving problems on large-scale computing machines.

In handling information, digital computing machines use the "binary" code. This means that combinations of two digits are needed to represent a number—the digit "1" and the digit "0." The 1's and 0's can be distinguished in many ways—by the presence or absence of electrical current, for example, by the punching or nonpunching of a hole in a card or tape, or by the absence or presence of a bit of magnetism at a selected spot.

With binary codes, it is very easy to detect mistakes by what is known as an odd-even check. For example, to provide an odd-even check for the code, 1101, the number of digits would be increased to five. The first four digits would carry the information and the final place would be for the check. Into this last place at the sending end of the circuit would be placed a 1, in order to make the total number of 1's in the symbol even, that is, zero, two or four.

Thus, with a check of this type, the symbol transmitted for the number 13 would be 11011, the 1 in the last position being put in to bring the total number of 1's to an even number, in this case, four. Suppose now, however, that a mistake is made and, due to some disturbance in the circuit, this symbol is received as 10011. The 1 in the second position has been lost in transmission. At the receiving end the odd-even check shows there should not be a 1 in the check position; but since a 1 is found there, it indicates that the quantity has been misrepresented by some malfunction during transmission. The receiving circuit is designed to indicate this fact by giving an alarm. In other words, the machine automatically caught itself in a mistake. While some early computers could do this,

Bell Labs retiree Richard Hamming is shown in a Bell Labs computer center in 1975. Today Hamming teaches mathematics and computer science at the Naval Post-Graduate School in Monterey, Calif.

they could not locate and thus could not correct the error.

If the circuit which found the mistake could also discover its exact position, however, the mistake could be corrected by reversing the digit in that position. Then, the machine could go on as though no error had occurred, and no operating time would be lost. This is what Hamming's codes made possible.

To accomplish this in the case of a number requiring four positions for transmitting information, an additional three positions are necessary. By having these three positions check different combinations of the four information-carrying digits, the exact location of any error can be determined and corrected. By adding an eighth position for a further odd-even check, the other seven digits can be examined for accuracy. In this way the machine is able to detect two simultaneous errors, although no information is given as to the location of either.

The theory that was developed by Hamming allows for the correction of any number of errors. It also provides means of checking numbers containing a large number of digits. Four-digit numbers were chosen for this particular example because of their relative simplicity. □

System speeds PBX services to business customers

Bell Laboratories engineers have developed a computer-based system that will enable Bell telephone companies to automate processing of *DIMENSION*® PBX service and repair orders for the more than 15,000 business customers in the nation with *DIMENSION* systems.

Called PICS/BARS, the system keeps a "real time" record of *DIMENSION* features and equipment for each business customer, as well as the spare parts kept by the company at warehouses and garages, to help speed service orders and repairs when needed.

"The initial version of PICS/BARS—Plug-in Inventory Control System/Business Administration and Records System—was developed in only six months," according to Ellis Courte, supervisor of the Business Administration and Records System Development Group, Piscataway, N. J.

Bell Labs use of common computer "languages" to develop various computer-based systems helps speed development and hold down costs.

Because the new system will reduce the need for Bell telephone companies to maintain large spare-parts inventories or to increase work forces, the total savings are expected to exceed $50 million for the Bell System over the next decade.

After a successful field experiment at South Central Bell, installation of PICS/BARS began recently at New York Telephone. Twelve more installations are scheduled in 1980, with most companies completing their installations by 1982.

The field experiment showed that the total time spent on service orders could be cut in half. Up-to-date records of *DIMENSION* stock in telephone company warehouses enabled service personnel to locate any piece of stock immediately, and to specify how soon—usually within five days—service changes or repairs could be effected.

PICS/BARS was designed to grow and meet changing customer needs. For instance, development is under way on a feature to link PICS/BARS with another computer-based system used for remote maintenance and traffic administration. This will enable telephone company representatives to change *DIMENSION* customers' line and trunk arrangements directly from the business office, where the change requests are received, and to automatically generate the associated records. □

News from Bell Labs

Bell Laboratories Record
May 1980

TSPS is first to use new 3B-20 processor

A new processor, the 3B model 20, will find its first Bell System field application in the Traffic Service Position System (TSPS). The 3B-20 provides greater storage capacity and processing capability—at lower cost—to support new service and operating features for both TSPS as well as the Stored Program Controlled (SPC) Network.

In the TSPS, which automates a number of routine tasks for toll operators, the 3B-20 processors will replace existing SPC 1A processors. The increased processing power and memory capacity of the 3B-20 will allow further enhancement of TSPS call-handling capabilities as new features are added.

For the SPC network, the 3B-20 will support improved toll-free "800" calling. And, through Common Channel Interoffice Signaling, it will also help provide automated billing services, which now require operator assistance.

The 3B-20 is the first in a family of general-purpose 3B processors now under development. A number of other applications are planned for members of the 3B family, including electronic switching.

The economy and versatility of the 3B-20 processor are made possible, in part, through the use of a 64,000-bit random access memory (64K RAM) developed last year by Bell Labs. They also are the result of new techniques in integrated circuit design and new developments in software. The 64K RAM employs "fault tolerant" circuit design, which allows the substitution of spare elements of

(continued on page D)

Study tool counts cost of plant alternatives

A new general-purpose, computerized study tool is helping Operating Companies compare economic investment alternatives for their nondiscretionary outside plant expenditures. Such expenditures typically deal with the installation, removal, rearrangement, or maintenance of outside plant equipment and facilities. For instance, a company might want to compare the relative merits of reinforcing aerial cable with placing new buried cable.

The new study tool, known as EASOP for the Economic Alternative Selection for Outside Plant, calculates the present worth of expenditures—that is, the worth in today's dollars of all cash flows associated with a project—for each alternative plan. EASOP incorporates AT&T's Capital Utilization Criteria (CUCRIT) subsystem in its calculation, so

(continued on page D)

Toll studies program incorporates CUCRIT

Economics plays an important part in the decisions Operating Company planners must make when they update and modify the Bell System's toll switching network. To help engineers conduct economic studies of alternative toll switching proposals, Bell Labs designed a computer-based interactive system—the Toll Alternatives Studies Program, TASP. To make sure TASP continues to be a useful planning tool, Bell Labs, with AT&T's support, continually looks for ways to improve the system. The third and latest version of TASP, known as TASP3, incorporates CUCRIT—the Capital Utilization Criteria program—which is the Bell System's standard economic and financial study aid for the Operating Companies. (See *Tipping the scales for No. 4 ESS*, p. 138 in this issue.)

CUCRIT evaluates the cost of different plans by taking into account many such factors as the cost of new equipment, its average service life, and state and federal tax rates. CUCRIT is already used as a stand-alone system for other kinds of economic analyses. It is part of economic planning programs like the Local Switching Replacement Planning System and the Metropolitan Area Transmission Facility Analysis Program.

Besides being a standard Bell System planning tool, supported by programmers in the AT&T Comptroller's organization, CUCRIT has other advantages over the economic study module previously used in TASP. As tax laws and economic analysis techniques change, revisions in CUCRIT can be readily implemented. In addition, many Bell System planners and managers are already familiar with CUCRIT, and a course in its use is available at the Bell System Center for Technical Education at Lisle, IL. The TASP Users Manual has been updated to reflect the changes caused in TASP by the incorporation of CUCRIT.

TASP3 was field tested in Sacramento and Phoenix during 1979. The system is now available to the Operating Companies. System Letter IL80-01-249 has more information.

Synthesized speech, braille let blind operators use TSPS

The Traffic Service Position System (TSPS) automates many of the routine aspects of the telephone operator's work. This frees the operator to serve more customers who have special calling needs. Operators at TSPS consoles rely on visual signals to help them do their job. Lamps give the operator such information as the type of call to be handled (for example, a station-to-station call or a request for operator assistance), while numerical displays show the time, charges, and calling number.

This dependence on visual communications has, until now, prevented blind operators from using TSPS consoles. To overcome this restriction, Bell Labs worked with Telesensory Systems, Inc., of Palo Alto, CA, to develop TIPS for the Blind. TIPS stands for TSPS Information Processing System. It uses braille and computer-synthesized speech to convey information that is normally shown by TSPS console lamps and numerical displays.

Bell Labs engineers designed a microprocessor-based interface unit that links the TSPS to TIPS for the Blind. The interface unit prepares information from the TSPS for input to TIPS. With the help of the interface unit, TIPS "translates" what would ordinarily be visual signals from the TSPS into forms that can be recognized by blind operators.

Information that would be presented as a numerical display is sent to an electronic braille panel that is placed on the TSPS console shelf. There the information appears as a series of raised dot patterns that the operator "reads" by touch. The TIPS speech-synthesis module generates announcements to alert the operator to changes in the condition of the TSPS console lamps. To receive the synthesized speech messages, the operator wears a special headset. And by depressing the proper keys on the electronic braille keyboard, the operator can have a message repeated.

Other features of TIPS for the Blind provide operators with additional help. For instance, the electronic braille panel is equipped with a "notepad." A braillewriter lets the operator record memos—such as the name of the person placing a collect call—for later reference. This feature also enables the operator to save numerical display information and other call data. Such information is occasionally needed to complete tickets for special billing. When the operator keys the proper code on the braille panel, information from the notepad is typed out on a line printer, and a supervisor completes the ticket.

With visual information adapted in these ways, blind operators can use the standard TSPS console keys to process calls without difficulty.

AT&T has developed a training package for teaching operators to use TIPS for the Blind, and field trials of this experimental system began during April in Sacramento.

With the help of a Bell Labs-designed interface unit, TIPS for the Blind converts TSPS information—normally presented to the operator visually by console lamps and digital readouts—into computer-synthesized speech and electronic braille displays. Bell Labs engineer Tom Benko demonstrates the braille panel, on the console shelf, and the specially designed headset for receiving synthesized speech messages.

Bell System readers are invited to use this card to offer comments, to ask questions about Bell Labs projects, and to request additional information about items in this section.

Reader Response Card

For Bell System use only

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Company

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May 1980

(If possible, please type or use black pen.)

Extra features added to loop test system

Bell Labs engineers have added six new test features to the Remote Test System—an electromechanical system which allows Operating Companies to evaluate customer loops that extend beyond the range of the Repair Service Center local test desk. The system is used where the test trunk has a total resistance greater than 1500 ohms.

Now Operating Companies can speed up cable repairs with a feature of the Remote Test System called "resistive fault sectionalization." This enhancement localizes resistive faults so repair crews can go directly to the faulty cable section. Two additional features—the noise measuring function and the line balance function—enable testers to gauge interference from induced noise and crosstalk more accurately.

A 577.5-Hz test tone is available to assist craftspersons in tracing circuit problems. The Remote Test System can perform checks on other loops while the test tone is being applied to a particular cable pair.

Finally, the enhanced Remote Test System tests coin telephone and rotary dial operations. The coin telephone test makes sure that remote equipment is collecting, totaling, and returning coins properly. This is done automatically, regardless of the length of the test trunk and loop. To test rotary dial operation, a craftsperson at the customer's location dials a specific number. The rotary dial analysis feature then counts pulses, measures dial speed, and calculates percent break—which checks that the dial relay is opening and closing as it should.

Remote testing capabilities are becoming more necessary as the Operating Companies continue to set up centralized Repair Service Centers to serve large geographic areas: Central offices terminating customer loops are likely to be further away from the Repair Service Center.

The Remote Test System can be used as a primary loop testing system. Where the Loop Maintenance Operations System and the Mechanized Loop Testing system are used to automate the Repair Service Center, the Remote Test System will provide backup facilities and will enable interactive testing between test desk personnel and craftspersons in the field. And because Bell Labs integrated the new features into the existing Remote Test System, minimal training is needed to teach Repair Service Center personnel to use them efficiently.

Field trials were conducted at the New Jersey Bell Repair Service Bureau at Dover. System Letter IL79-05-310 has more information.

New manhole cover design gives craftspersons a mechanical advantage

Bell Labs engineers are always looking for ways to improve Bell System equipment, and at the same time to make the jobs of the people who work with that equipment easier. Bell Labs has recently designed a lighter, stronger, and more watertight manhole cover.

The new cover weighs 70 pounds less than the widely used standard B cover, and it is equipped with a gasket that helps keep surface water out of the manhole. Rather than the conventional flat plate with radial ribs and concentric rings, the undersurface of the new cover is convex, putting maximum thickness in the center where it is needed most to withstand traffic loads.

In addition, a lever-action lifter tool was designed to be used with the new cover. (It can also be used with the standard B cover.) With the lifter tool and the lighter cover, it will be easier for craftspersons—especially those of slight stature—to access below-ground cable and equipment.

A locking version of the new cover is also available. Two captive bolts secure the cover to the frame.

Field trials of both the nonlocking cover and the redesigned lifter tool were conducted in New Jersey and Illinois. A human factors evaluation was held at Bell Labs in Chester, N. J.

Engineering Letter 6641 has more information about the new cover and lifter tool.

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3B PROCESSOR (cont.)
memory for imperfect ones during production. This reduces waste and increases the yield of working chips.

Another cost-saving factor is the 3B-20 processor's use of custom gate array integrated circuits. In gate array devices, standard arrays of logic elements (gates) are prefabricated on silicon chips. Then, custom-designed metal pathways are added to provide connections between elements. This approach to large-scale integration reduces the time between design and production. It also makes it possible for 19 applications in the 3B-20, based on only four custom designs, to replace 329 general-purpose, small-scale integrated circuits.

In addition, a new *UNIX*™-based operating system—the Duplex Multi Environment Real Time (DMERT) system—has been developed for the 3B processor family. It provides features for central office operations, including software packages that allow craftspersons to perform local and remote maintenance. The system also permits data bases to be updated at the same time equipment changes are made.

3B-20 processors are already operating in test laboratories at Bell Labs and Western Electric. Field tests for the TSPS application of the 3B-20 are now being conducted by Bell Labs and Western Electric at the Southwestern Bell San Antonio office, with commercial service scheduled to begin there in September 1981.

For more information about the articles in this issue, please get in touch with the authors at the addresses listed here. For Indian Hill room locations use Bell Laboratories, Warrenville-Wheaton Road, Naperville, IL 60540.

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► **Signal processor sorts sounds from the sea**
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► **Planning for people: human factors in the design of a new service**
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T. MICHAEL BAUER
Room 6K-333—Indian Hill
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► **No. 4 ESS growth: serving increased toll switching needs**
EDWARD A. DAVIS
Room 4C-309—Indian Hill

EASOP (cont.)
present worth results will always be consistent with current tax laws and basic engineering economy concepts. There is no need for the engineer to enter cost data, because EASOP uses a prestored cost data base tailored individually to each company's or area's published average costs. The engineer may override specific cost data if they are inappropriate for a particular study.

EASOP replaces the Time-Share Outside Plant Present Worth Study (TOPPS) program used by many Operating Companies. Because TOPPS was developed in the early 1960s, before inflation, accelerated depreciation, and the investment tax credit became important factors in cost analysis, its economic methodology is outdated. EASOP is more flexible than the TOPPS program, requires less time to use, and produces reports that are more accurate and easier to interpret.

EASOP was released for general Bell System use last year after field trials at Bell of Pennsylvania and New England Telephone. The program is available now as a Western Electric Engineering, Planning, and Analysis Systems (EPLANS) offering.

Dialing instructions. Among the trial stations used in evaluating an automated credit card service concept were 70 coin phones. Placards directed customers in the use of the trial service. Bell Labs human factors engineers tested several placard designs to find out which format was the most helpful to customers.

Planning for people:

Human factors in the design of a new service

Human factors evaluations help Bell Labs design new services with high customer acceptance and low user errors.

MARK R. ALLYN, T. MICHAEL BAUER, AND DARYL J. EIGEN

Every time a customer dials a telephone call, he or she interacts with the telecommunications system. Human factors—human abilities, attitudes, and perceptions—affect how people and systems work together. And Bell Labs human factors engineers play a key part in the design of nearly all new services that reach Bell System customers. Their goal is to make it easier for customers to use these services accurately and efficiently.

Bell Labs human factors engineers evaluate the design of potential new services and future service concepts. One way they do this is to set up test systems in the field. Under actual operating conditions, engineers systematically manipulate service components—the elements, like dialing procedures and the wording of written and recorded instructions,

that make up a service "protocol." Human factors engineers monitor the effects of these changes to determine which combination of service components provides the highest customer use and acceptance, and leads customers to make the fewest errors.

Recently, Bell Labs and AT&T evaluated a future service concept—automated credit card calling—in an Operating Company environment. This service concept would allow customers to bill calls to a phone other than the one from which the call originates, without the need for an operator's help—just as Direct Distance Dialing provides long-distance telephone service billed to the originating telephone without operator assistance. Such a service would be expected to cut costs, since the customer, not an operator, enters the billing information for the call. The service would also help handle the rising volume of specially billed calls the Bell System predicts for the next two decades.

The design of an automated credit card service would be based on the results of an evaluation that began in November 1977. Wisconsin Telephone hosted the trial, which lasted about seven months. The trial was especially noteworthy because of the large number of service components studied, and the amount of data collected and analyzed.

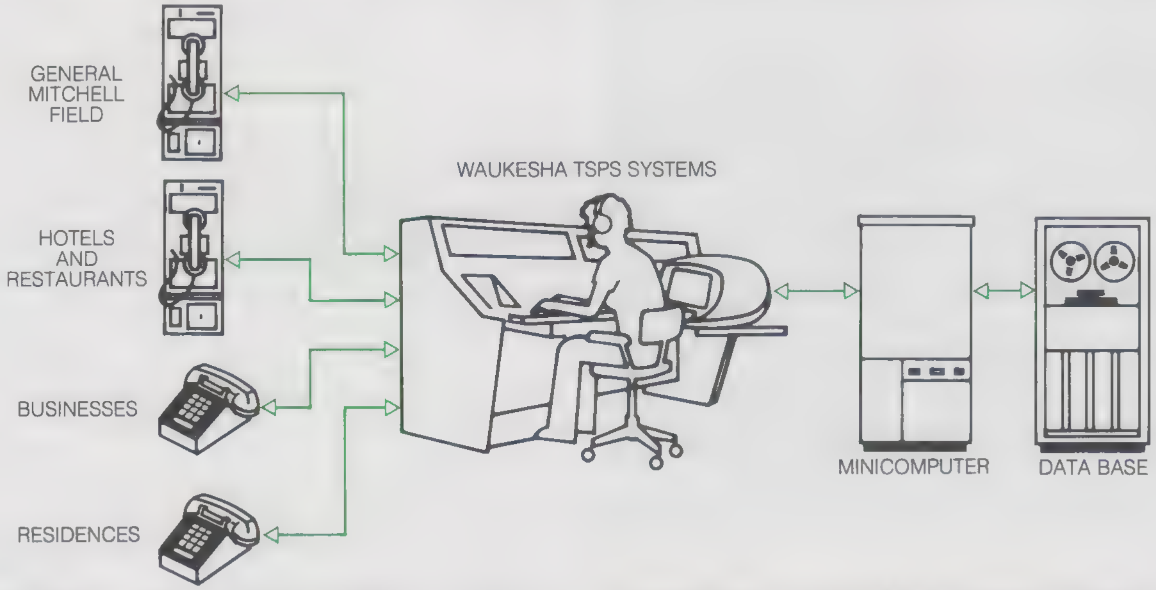
Bell Labs obtained the names of potential trial participants by computer analysis of billing records from five Milwaukee area business offices. Candidates were chosen from among customers having credit card, collect, and third-number-billed calls listed on their accounts. Customers expressing an interest in the service were given details of the offering and invited to participate in the trial. In all, 425 business and residential accounts were signed up for the evaluation, which was offered under a trial tariff.

How the trial service worked

Wisconsin Telephone assigned each customer subscribing to the trial service a unique number consisting of the billing number (ten digits) followed by a personal identification number (four digits). This composite number could be used to place calls from any of about 3000 noncoin stations in the Milwaukee area, and from 70 coin stations at Milwaukee's airport (General Mitchell Field), at two downtown hotels, and at a few local restaurants.

Brochures prepared by AT&T, and in-person instructions given by Wisconsin Telephone marketing representatives showed trial participants how to use the service. Instructions were also printed on the special credit service cards given to the participants.

To use the automated credit card service, customers first dialed 0 plus the number they wished to call. This connected them to the Waukesha Traffic Service Position System (TSPS). Special stored program instructions in the TSPS routed incoming "0+" calls from trial



Test setup. A team of operators handled 0+ calls from the trial stations. Each operator had a Traffic Service Position System console and a video display terminal. The terminal was connected to a minicomputer, which collected data on each call and presented guidelines—via the terminal screen—to direct the operator in processing the call, and in simulating recorded announcements. In an actual service, no operators would be used.

stations in the Milwaukee area to a small team of specially trained operators who helped simulate an automated service, where no operators would be used. Besides the TSPS console, the operators had a video display terminal linked to a minicomputer.

When a call came into the TSPS, the operator used the terminal to notify the minicomputer. The minicomputer then activated hardware at the TSPS, which delivered a tone to prompt customers to dial their billing and personal identification numbers. As a special convenience, customers calling their own billing number had only to dial their personal identification number to have the call automatically charged to their account. The minicomputer was programmed to allow a set interval between the time the customer dialed a fourth digit and when he or she dialed a fifth digit. If during that time the customer did not dial a fifth digit, the minicomputer inferred that the customer had dialed a four-digit personal identification number and that he or she was not dialing a billing number.

Signal detection circuits received the dialed digits and sent them to the minicomputer over a data link. The minicomputer processed the digits to determine the validity of the billing and personal identification numbers. Calls with valid numbers were completed and charged to the billing number.

Operator instructions

Depending on the set of service components, or protocol, being tested, the minicomputer displayed step-by-step instructions on the terminal screen to guide the operator in handling each call. For example, if Bell Labs human factors engineers were looking for ways to encourage customers to redial after making errors, the minicomputer might ask the operator to tell the caller: "Please hang up and dial zero plus the number you are calling." Or, if engineers were studying different methods for improving customer response, the minicomputer might direct the operator to acknowledge a successfully dialed number by saying, "Thank you." (For more about announcement wordings, see panel, page 160.) By making a small change in the minicomputer program, engineers could alter the operator's treatment of a call.

Operator-spoken announcements simulated recorded announcements. To deliver announcements, operators momentarily activated a talking path to customers by depressing a special button added to the TSPS console.

If customers wished to speak with an operator, they could do so by either dialing 0 again after the called number, or by not dialing after the prompt. Customers who dialed 0 reached an operator more quickly than customers who did not dial 0. If customers didn't want to dial their billing number, or if they dialed from nontrial stations served by the Waukesha TSPS, they could give their number orally to the operator, who would then enter it into the TSPS.

The minicomputer recorded the time certain events occurred during each call. The timing and sequence of call events were later analyzed to determine if and when a customer abandoned dialing, how long it took the customer to dial the number, how long the customer waited between dialing individual digits, the customer dialing error rate, the number of tries before successful dialing, and so forth.

Varying the protocol

Bell Labs human factors engineers and systems engineers worked with AT&T marketing and operator services specialists to select service components for the initial trial protocol. Throughout the trial, Bell Labs engineers varied key service components such as the use of tones and announcements to prompt dialing; the wording of operator instructions; the amount of time between events—for instance, between a prompt announcement and the time a nondialing customer was connected to an operator; the procedures customers followed after a dialing error; and the ways customers could reach an operator. Twenty-three variations of the initial protocol were tested at trial coin stations, and 13 were tested at trial noncoin stations. (See panel, pages 158 and 159, for some details of how service component variations were evaluated.)

In theory, an ideal service would have all customers who wished to use it dialing their billing numbers successfully. All others would dial 0 to reach an operator sooner than by not dialing and simply waiting for an operator. In practice, this is not generally possible: The best service was one that maximized successful dialing and customer satisfaction, and minimized abandonments.

The success of new services depends on how customers view them. AT&T, Bell Laboratories, and two independent public opinion firms conducted interviews—both face-to-face and over the telephone—to measure overall customer attitudes toward the proposed

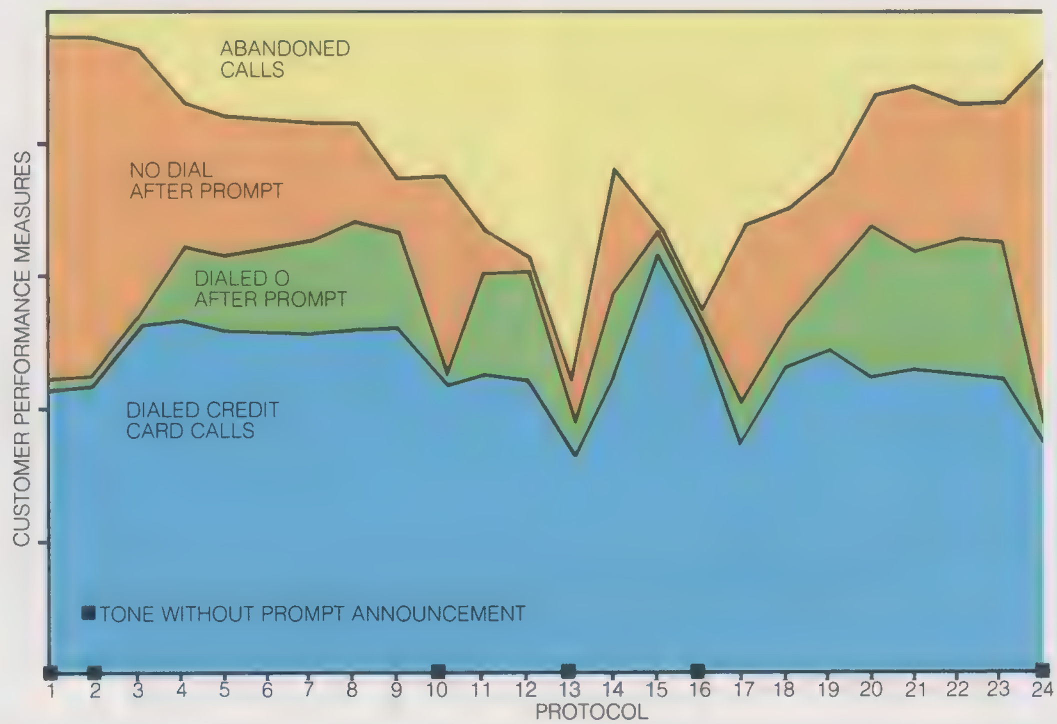
Evaluating the results

Throughout the trial of automated credit card calling, Bell Labs engineers monitored four primary measures of customer performance. These were the numbers of customers who:

- dialed their billing and personal identification numbers or credit card numbers successfully;
- dialed O after the prompt in order to reach an operator;
- reached an operator by not dialing after the prompt;
- abandoned the call.

The graph shows how these measures varied as engineers changed protocols, or sets of service components, at coin stations with placards giving dialing instructions. The colored area beneath each curve represents the interplay of several service components. The table shows some of the major components tested by each protocol.

Some variations in protocol had a significant effect on customer behavior. For example, some protocols used a tone without an announcement to prompt cus-



service, and toward specific protocols. Data were collected in over 5000 interviews.

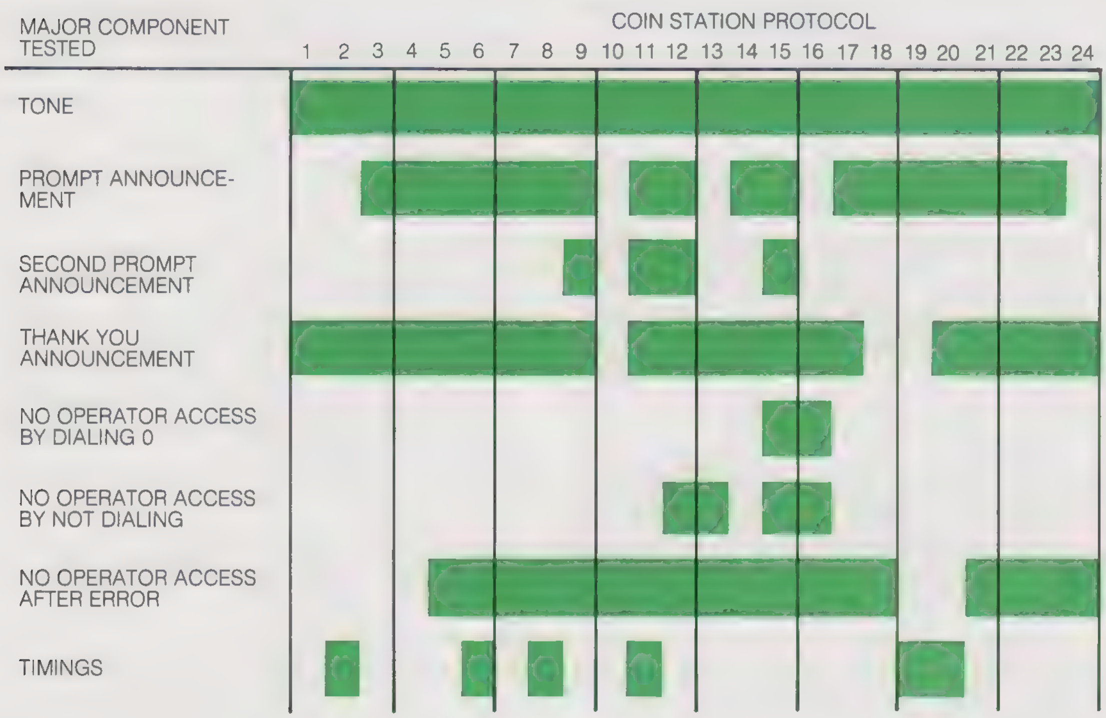
During January 1978, Bell Labs researchers expanded the evaluation to allow all telephone customers with a valid conventional credit card number to dial from the trial stations. Most of this conventional credit card traffic originated at airport coin stations. Placards above the coin stations and instructions given by the operators guided customers using the automated service.

Bell Labs engineers took this opportunity to experiment with placard wording and format. Usage and acceptance measures were recorded for each of five versions; data were also gathered from coin stations without placards. With this information, engineers determined whether a placard should be used, and if so, what would be the most effective design. The experiment showed that instruction placards substantially improved dialing. When an announcement was used to provide dialing instructions in addition to the placard, there was an even greater improvement. And in in-

tomers to dial their billing and personal identification numbers or credit card numbers. The presence of an announcement made a difference in the number of successfully dialed calls (dialed credit card calls and calls for operator assistance). Another set of protocols did not permit customers to reach an operator by just waiting (not dialing) after the prompt. This affected abandonments. Other protocols affecting abandonments tested the effect of repeating the prompt announcement whenever the customer failed to dial after the first announcement.

Protocols that showed good results—they produced a relatively low number of abandonments and a relatively high number of successfully dialed calls—contained service components such as improved announcement wordings (without the repeated prompt announcement), adjusted timings, and a "thank you" when customers dialed accurately.

Data like these, combined with interview results, helped engineers select the most effective set of service components.



terviews, a large percentage of the credit card customers who called from the trial stations judged the placards to be clear and easy to follow.

By the end of the trial, over 10,000 customers from all over the country had used the automated credit card service to place more than 30,000 calls. These calls provided ample data to gauge the effects of different protocols on customer performance and attitude.

A data base was created to store the information collected during the evaluation. The data base held about 35 million bytes of information.

Bell Labs designed computer programs to organize, integrate, and analyze this volume of data. These analytical tools allowed engineers to evaluate incoming information efficiently, and to vary the trial protocols quickly in reaction to findings. Engineers thus were able to evaluate many more service component variations than otherwise would have been possible during the limited trial period.

Enough data were collected during the trial

of each protocol to ensure reliable results. Engineers repeated certain service variations at different times during the evaluation to make sure that results were not attributable to pure chance. For example, when an airline flight was canceled, there would usually be a sharp increase in automated credit card calling from the airport trial stations. This increase was not due to the particular protocol being tested; by retesting that same combination of service components at another time, engineers obtained more realistic results. They also simultaneously tested different protocols at separate groups of trial stations. If the percentage of customers dialing correctly dipped at one group of stations and rose at the other, the disparity was probably due to the difference in protocols, since all other factors surrounding the test were essentially constant.

The two most successful protocols—that is, the two that produced the greatest customer satisfaction, the highest percentage of successfully dialed calls, and the fewest abandonments—underwent an extended evaluation to provide stable data on customer performance and acceptance. Based on information from the trial, Bell Labs human factors engineers selected the "best" automated credit card service protocol.

Among other features, the potential service would have an announcement in addition to a tone to prompt callers to dial their credit card numbers. During the trial, this combination yielded consistently more successful dialing than use of the tone alone. On the other hand, repeating the announcement was not helpful—it caused an increase in abandonments, with no increase in successful dialing. A "thank you" announcement after a customer dialed successfully, however, did

Looking for the right words

The trial of the automated credit card service concept tested different ways of prompting customers to dial their billing and personal identification numbers or their credit card numbers. A tone followed by an announcement encouraged more people to dial than a tone only.

Human factors engineers wished to find out the announcement wording that produced the highest percentage of successfully dialed calls, the lowest percentage of abandoned calls, and the maximum customer satisfaction. These criteria were sensitive to changes in announcement wording—a single word-change could alter customer behavior significantly and influence customers' overall reaction to the trial service. The first wording engineers tried was:

Dial your card number, please.

By monitoring service and conducting interviews, the engineers found that this announcement confused many users—they talked to the announcement, thinking they were connected to an operator.

Working on the assumption that the critical word "dial" was being misunderstood because it was the first word of the announcement and took customers by surprise, engineers placed "please" first:

Please dial your card number.

This improved the percentage of people successfully dialing their calls, and reduced customer confusion. Still, some customers continued to speak to the announcement as if it were an operator. In the next trial variation, the announcement was made more explicit:

Please dial your card number
or zero for an operator.

Engineers again monitored service and interviewed customers. Results showed that telling customers how to reach the operator made it clear to most that they were listening to an announcement. In addition, if customers requiring operator assistance dialed O, they could obtain an operator faster than if they chose not to dial and wait. This improved customer satisfaction with the service.

Other variations in wording were tried, but the best results were obtained with:

Please dial your card number
or zero for an operator now.

The addition of the word "now" eliminated dialing delays by making it clear to customers that immediate action was expected of them. In almost no instance did customers attempt to speak to this announcement.

Building on experience

The needs and capabilities of customers have, from the start, been uppermost in the minds of those who design Bell System telephone systems and equipment. The trial of automated credit card service benefitted, at least indirectly, from the knowledge gained in many previous human factors studies.

In the early 1920s, Bell System investigations of human speech and hearing led to standard designs for efficient, high-quality, voice-frequency transmission circuits. And later studies of user preferences pointed to ways telephone handsets and coin telephones could be improved.

The telephone dial and dialing procedures have received much attention over the years. For instance, human factors work during the 1940s proved that most people would not only accept all-number dialing, but that conversion to seven-digit phone numbers would allow customers to dial faster and with greater accuracy.

Other research helped in the design of easier-to-use dials. As a result of one human factors study, the angle of the table-model phone dial was lowered from 45 degrees to 26 degrees for better visibility. And a dot was placed in the center of each hole of the rotary dial after another investigation showed that this modification would improve dialing.

When *TOUCH-TONE*® dialing first came into wide use in the late 1960s, customers were benefitting from extensive human factors testing of the new key pad. Before engineers settled on the current arrangement, they studied variables like the force required to depress the keys, and the optimum key size and layout.

Human factors considerations also played a part in designing the systems and equipment that provide customers with operator services. When operators use the TSPS console, the speedy service they provide to customers is, in part, due to human factors research. Designers studied human perception, memory, and information processing to organize the console keys for greatest operator efficiency.

Considerable research lies behind the "scripts" for recorded announcements. Studies analyzed the effects of different wordings, pauses in speech, and voice pitch. Recently, these findings helped guide the design of Automated Coin Toll Service, a service that automates coin toll-call operations by calculating charges, telling the customer how much to deposit, and counting deposited coins.

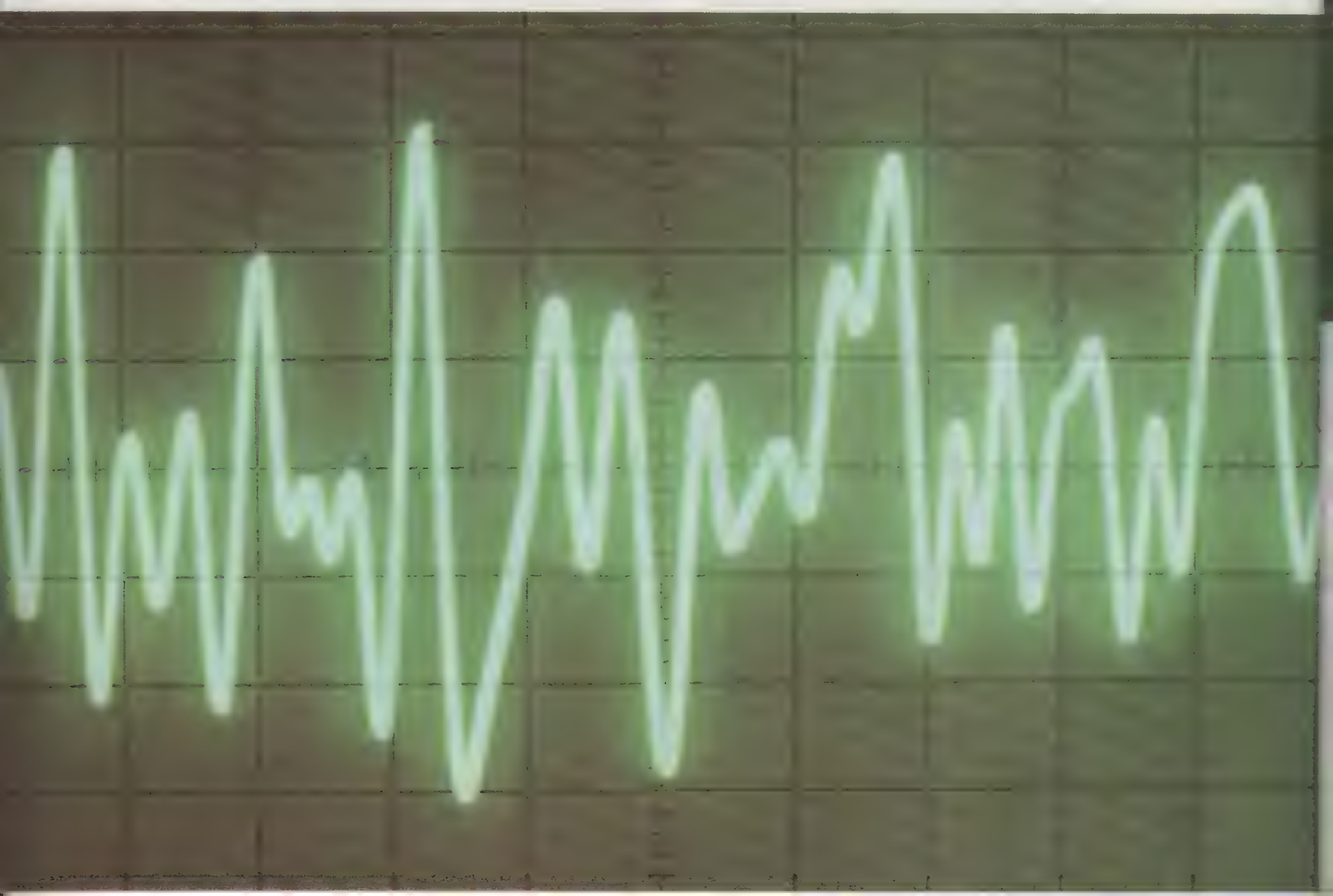
Human factors experts at Bell Labs are involved in the design and development of almost all Bell System products, services, and systems used by customers and employees. And they are continuing the search for improved tools and methods for studying human behavior and human-machine interaction.

tend to reduce abandonments.

Such a service would also have an announcement asking the customer to dial a second time if an error was made in dialing, or if the customer dialed an invalid number. Tests showed that a third chance at dialing yielded a very small incremental improvement in dialing.

Human factors evaluations play an integral part in planning the requirements for developing new services. These requirements help Bell Labs hardware, software, and systems engineers design a network-compatible service with the user in mind. This design effort may include specifying the general contents and organization of a nationwide data base, establishing interoffice signaling arrangements, and designating Automatic Message Accounting procedures, maintenance procedures, and service observing techniques, among other considerations.

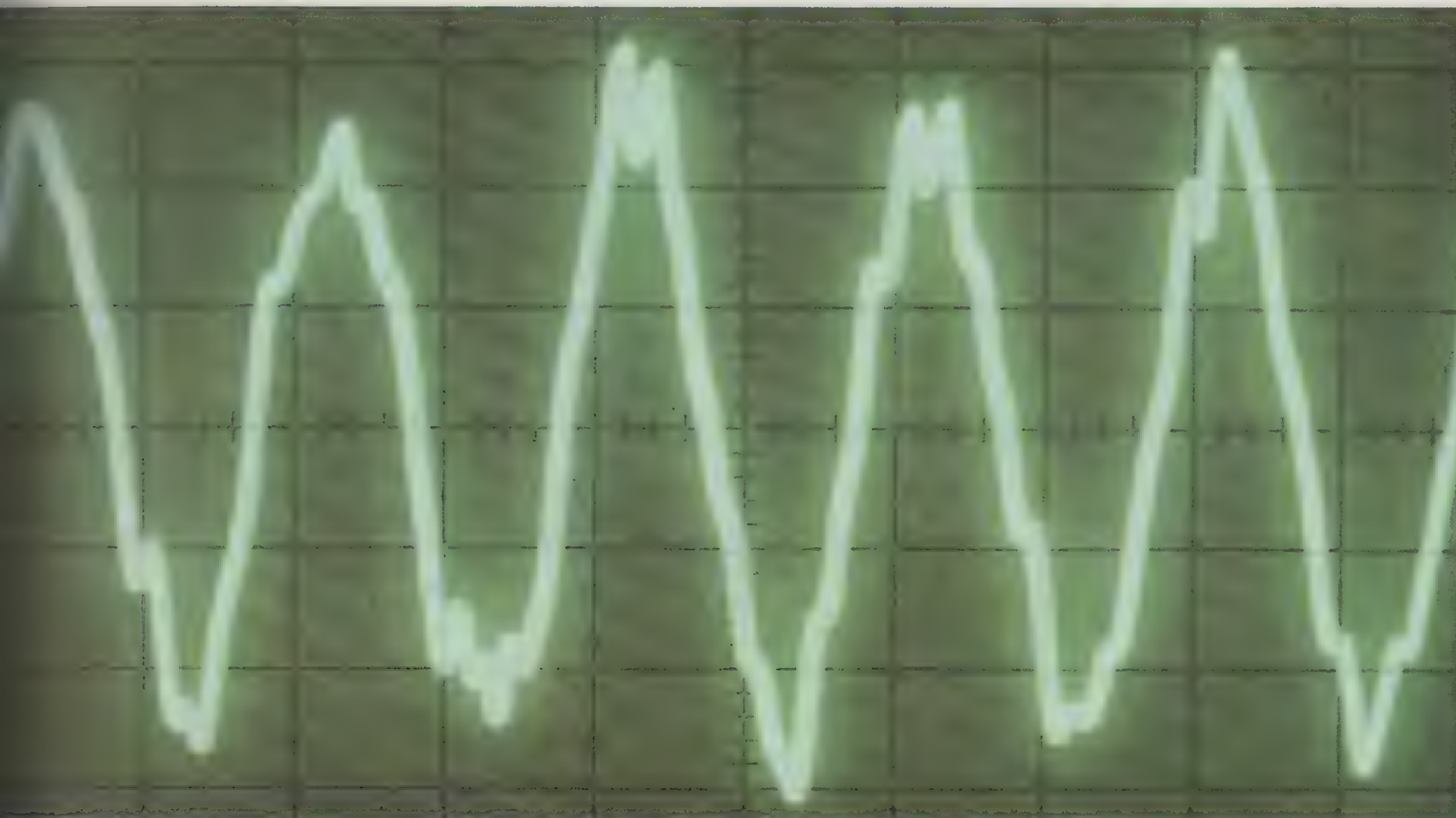
For nearly 60 years, Bell System designers have been studying the complex interactions between people and telephone systems. (See panel, above.) Just as the collected body of human factors research provided the groundwork for the trial of a potential automated credit card service, the findings of this study will help to guide the design of still other network services that involve customer dialing and nationwide data bases. As a result, customers will receive better and faster service on routine calls, and Operating Companies will be able to hold down costs. □



Signal processor sorts sounds from the sea

Load sharing, used in many ways throughout the Synchronous Distributed Processor, is the key to its speed.

UMBERTO F. GIANOLA AND RICHARD R. SHIVELY



Sound waves—from whale songs, ships' engines, underwater blasting, intense storms—traveling together through miles of ocean become jumbled, distorted, attenuated. To isolate the sound from a single source, a listener must collect all sound waves, separate the desired one from the others, and perhaps rebuild it into a coherent signal.

To collect the sounds, oceanographers and the U. S. Navy use a very sensitive underwater microphone called the hydrophone. To separate the desired sound from all the others, these listeners use arrays of hydrophones, which collect slightly differing copies of the barrage of sound waves, and a special computer that manipulates the copies to isolate particular waves (see *Tuning in sound waves under the sea,* RECORD, January 1980).

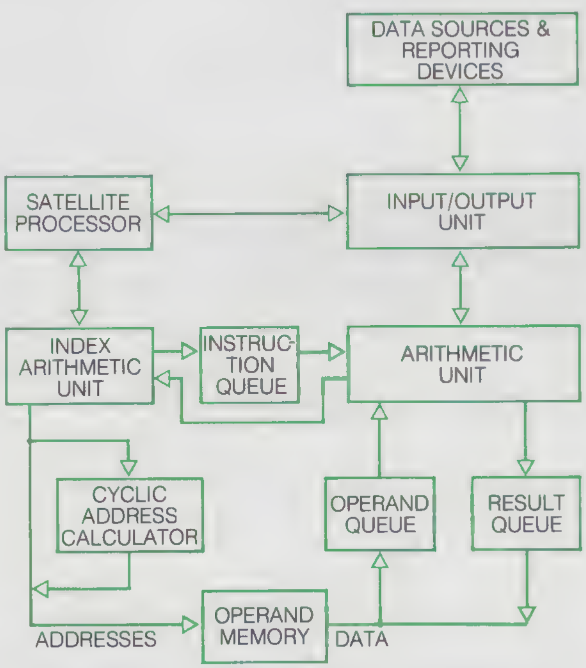
This computer is called a Synchronous Distributed Processor (SDP). It was developed by Bell Labs to locate and separate undersea sounds. A member of the class of computers called signal processors, it performs repetitive multiplications and additions on masses of

Clear sounds. Arriving at the processor are many jagged waves like those at left; leaving it is a clarified wave like the one above. The output wave, a component of the input waves, is highly magnified here.

data very quickly and economically.

Picking one sound out of all those in the sea requires this data-processing capability, as a separation technique called beam-forming will demonstrate. Hydrophones arranged at intervals in a linear array sense the same sounds. Because they differ slightly in distance from the sound sources, however, they receive the sounds at slightly different times.

The operator of the system knows the distances between hydrophones, and can compute the differences in time for each direction. By a series of mathematical operations, the signal processor can delay the hydrophone signals from one direction so they all seem to arrive at the same time—but only the sounds from that particular direction will be simultaneous. Then, the processor adds the signals together. Sounds that arrive "together" reinforce each other when combined; those from other directions—for which delays are not set—cancel each other out when combined. This difference permits the operator of the system to tune in certain sounds; by changing the delays, the processor can electronically change the "direction" of the hydrophone beam, much as phased array radars steer microwave transmitting and receiving beams electronically.



Anatomy. Major parts of the Synchronous Distributed Processor include the input/output unit, the arithmetic and index arithmetic units, the satellite processor, the cyclic address calculator, and various memories. The queues in this drawing are first-in, first-out buffer memories.

The signal processor must perform several analytical operations, such as band-pass filtering (selecting sounds in a certain frequency band), when forming a hydrophone beam. It also does operations such as spectrum analysis (plotting a signal's strength versus its frequency) to isolate sounds in other patterns. Each such operation—involving several multiplications and additions—must be done on perhaps thousands of samples per second from each hydrophone signal. And each sample is processed in real time—as it arrives. This task requires great computing speed.

Load sharing

The SDP is designed for speed. Its clock is set so that the processor does a new set of operations every 125 nanoseconds (billionths of a second), the processor's cycle time. And, every 125 nanoseconds, 8 million times per second, it produces another sum and product. Each of these results is one step in the manipulation of one datum—one sample of one sound wave.

The SDP's speed is a result of its "architecture": the way data are routed through the various operations, and the way the components doing the operations are used. Like other signal processors, the SDP uses load sharing techniques, which ensure that every component is fully used as much of the time as possible. Tasks are broken into several parts, and each part is done by a different, specialized unit. Where an auto mechanic might assemble one car, sell it, and then begin a second, an organization using load sharing would have separate sales and assembly staffs. And within the assembly plant, no lug wrench would lie idle while the mechanic stitched up the upholstery: The mechanic with the lug wrench would always install tires; the upholsterer would constantly ply the needle; and both would receive material and provide finished products at the proper rate.

The SDP differs from a typical general-purpose computer in the extent to which its functions are shared, or distributed, among its components—hence the "distributed" in its name. (It is called "synchronous" because all of its components are synchronized to the same internal clock.) The general-purpose computer might have two components working side-by-side to increase capacity at some tasks; in the SDP, nearly all tasks are broken into segments and shared. The processor also distributes the task of storing data and instructions, rather than concentrating both

in a central memory. This makes retrieval faster.

The SDP differs from some other signal processors. It is programmable: Many other processors are designed for specific jobs and cannot easily do different ones. And it is faster and has more memory than many.

A typical operation

The beam-forming process might begin with filtering. Successive samples of one analog wave are multiplied by coefficients—specific numbers calculated and stored in a coefficient memory; the series of products is added together; and the results are stored for other manipulations. Following this procedure through some of the machine's major components—its input/output unit, arithmetic unit, index arithmetic unit, memories, and satellite processor—will demonstrate the SDP's architecture and operating principles.

As it enters the SDP, the signal from a hydrophone is converted from analog to digital—that is, samples are taken and expressed as digital words, or groups of ones and zeroes. The samples are multiplexed, or interleaved, with samples from all other hydrophones in the system.

These multiplexed samples go into the processor's input/output unit, where they are stored until the arithmetic unit is ready to work on them. As its name suggests, the latter unit does all the adding and multiplying. Differing from a normal computer, however, it performs whole sequences of arithmetic operations—such as filtering—without requiring step-by-step instructions. This greatly eases the software designer's job, speeds the processing, and reduces errors.

At regular intervals, the arithmetic unit calls for a batch of samples from a small storage unit called the input queue. This is a first-in, first-out unit that keeps a supply of samples ready for the arithmetic unit.

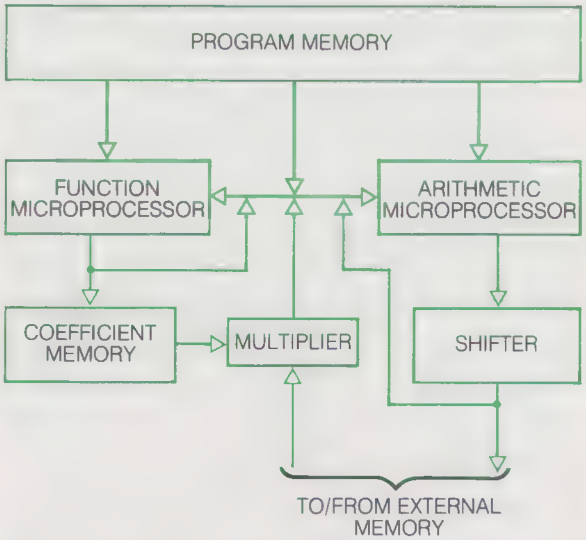
As a sample reaches the head of the queue, it is taken into the arithmetic unit, along with the coefficient by which it must be multiplied. Both coefficient and instruction are stored inside the arithmetic unit. The arithmetic unit contains two microprocessors—the arithmetic microprocessor (AM) and the function microprocessor (FM)—and two multipliers. In this example, the two microprocessors work on different parts of the task. The FM retrieves coefficients from the coefficient memory, while the AM adds. (In other operations, the two microprocessors might both add.) Samples and coefficients go to the multipliers alternately. Multiplication takes two cycles, but use of two multipliers, working in tandem, gives an effective multiply rate of one per cycle.

The product of the first sample and its coefficient leaves the first multiplier and goes into the arithmetic microprocessor, to be joined at 125-nanosecond intervals by the second, third, and so on. The AM adds them together, or "accumulates their sum." The final result of filtering the first series of samples is moved out of the arithmetic microprocessor and out of the arithmetic unit to a memory to await the next operation.

This sequence involves two design techniques, called parallel processing and pipelining. (See the panel on page 166.) The multipliers work in parallel; the input queue, multipliers, arithmetic microprocessor, and result queue are parts of a pipeline, or assembly line.

After the arithmetic unit filters samples from the first hydrophone, it filters samples from the other hydrophones that were multiplexed into the input. Every few cycles, it can turn to a different hydrophone. Every few milliseconds, it can switch from filtering to a completely different operation such as spectrum analysis.

Every cycle, the parts of the arithmetic unit turn out at least one new product and sum.



More memories. The structure of the arithmetic unit illustrates the distribution of memories and other components that make the SDP so efficient and fast. The unit can retrieve instructions and coefficients from its own storage. When needed, the function microprocessor can do sums along with the arithmetic microprocessor; otherwise, it does administrative work.

Architectural techniques

COMPONENT \ CYCLE NUMBER	1	2	3	4	5	6	7	8
SAMPLE INPUT QUEUE	SAMPLE NO 1	SAMPLE No. 2	SAMPLE No 3	SAMPLE No 4	SAMPLE No. 5	SAMPLE No. 6	SAMPLE No. 7	SAMPLE No. 8
COEFFICIENT MEMORY	COEFF NO. 1	COEFF. No 2	COEFF No 3	COEFF No 4	COEFF No. 5	COEFF. No. 6	COEFF. No 7	COEFF. No. 8
MULTIPLIER 1		SAMPLE & COEFF. No 1		SAMPLE & COEFF. No. 3		SAMPLE & COEFF. No. 5		SAMPLE & COEFF. No.7
MULTIPLIER 2			SAMPLE & COEFF No. 2		SAMPLE & COEFF. No 4		SAMPLE & COEFF. No 6	
ARITHMETIC MICROPROCESSOR				PRODUCT No 1	ADD PRODUCT NO. 2	ADD PRODUCT NO. 3	ADD PRODUCT NO. 4	ADD PRODUCT NO 5

Two architectural techniques that make the Synchronous Distributed Processor (SDP) fast are parallel processing and pipelining. In both, the load is shared among different components that individually may not be as fast as the processor has to be. Parallel processing means using two or more identical units side-by-side (like the SDP's two multipliers), or doing related operations simultaneously in different units (the way the arithmetic unit computes while the index arithmetic unit locates samples and instructions). Pipelining is the division of a task into parts, giving each to a component that does only that task and no other: The task moves from component to component.

The multiplication and addition in band-pass filtering demonstrate how these techniques work. The sample and the coefficient by which it is to be multiplied line up, in, respectively, the input queue and the coefficient memory. When their turn comes, they go to a multiplier to be multiplied; their product goes to the arithmetic microprocessor to be added to the products of other sample-coefficient multiplications; the resulting sum goes to a shifter, which scales it down if the sum is too large to be written in 16 bits; and then the result goes to a result queue.

In a general-purpose computer, these operations might be done sequentially by the same arithmetic components. If the process up to the summing took five machine cycles, the unit would produce one sum every five cycles. The SDP, however, produces one sum every single cycle. Multiplication takes two cycles, so the SDP has two multipliers that take samples and coefficients alternately; between them, they turn out a product every cycle. The other operations—retrieving the sample and coefficient from their respective memories and adding the newest product to the others—each take one cycle. The SDP assigns each of these tasks to a different component and arranges the components in a pipeline.

As the chart illustrates, sample and coefficient No. 1 are retrieved on cycle No. 1. On cycle No. 2, sample and coefficient No. 1 go to multiplier No. 1; and sample and coefficient No. 2 are retrieved. On cycle No. 3, the multiplication of sample and coefficient No. 1 continues; sample and coefficient No. 2 go to the second multiplier; and sample and coefficient No. 3 are retrieved. On cycle No. 4, product No. 1 is moved to the arithmetic microprocessor to await the next product; the multiplication of sample and coefficient No. 2 continues; sample and coefficient No. 3 go to the first multiplier; and sample and coefficient No. 4 are retrieved. On cycle No. 5, product No. 2 joins product No. 1 in the arithmetic microprocessor, which adds them to get their sum, and all the other operations advance one step. The pipeline is now full: Every cycle, the arithmetic microprocessor receives another product to add to its sum. When the series of, say, 15 samples is finished, the final sum goes to the shifter and then the result queue—while the multipliers and arithmetic microprocessor are already processing the next series.

The arithmetic unit can persevere at this pace because it needn't do anything else. It has a coordinator, called the index arithmetic unit, which makes sure that the right datum, and the right instruction on what to do, arrive on the right cycle.

The index unit retrieves operands (data to be processed) from the several memories in the SDP, and interleaves operations as needed. Thus, it might place in the operand queue several hundred new samples with instructions to the arithmetic unit to filter them. Next in the queue it might place summaries of results with instructions to do a spectrum analysis. The arithmetic unit has the instructions for each operation in its own memory, and calls them up as ordered by the index unit. When the arithmetic unit finishes an operation, it puts the results in the result queue, and the index unit takes them away for storage. When all operations have been done, and one sound wave has been isolated, the final data —the output—are sent back out through the input/output unit.

The SDP has another unit called the satellite processor, which oversees peripheral units such as terminals, and does other administrative tasks not synchronized to the internal clock. This unit does all the organizational tasks not directly related to the steady work of the arithmetic unit, including filing diagnostic reports. It may call for a change in the procedures used and perform certain background tasks. If an error occurs, the satellite unit can restart the SDP program to try again.

Special features

Load sharing techniques such as parallel processing and pipelining are largely responsible for the SDP's speed. Several hardware features enable the load sharing to work especially smoothly, and greatly simplify the software design job of programming the SDP for new applications. In addition to those already mentioned, the SDP uses a cyclic address calculator, small buffer memories, and distributed large memories.

Signal processing operations are usually done not on just one sample but on a number of the most recent—say, fifteen. These must be retained in the arithmetic unit's memory. Each time a new sample arrives, the oldest of the fifteen is eliminated.

The job of keeping track of sample locations could be done by the software programmer—as is required by most computers—but the SDP avoids that complication through use of special self-sufficient hardware. With its use, the newest sample is written over the oldest, the others remain in their original places, and the cyclic address calculator figures out the address of the new one—and automatically sends the data series out in the right order when the arithmetic unit asks for it. This saves readdressing and makes retrieval faster. Features like this are said to be "transparent" to the program—that is, the software designer does not have to include detailed instructions for them in the program.

FIFO memories

Another self-sufficient memory retrieval and placement feature ensures that data are available in the right place, in the right order, and at the right time. Small first-in, first-out (FIFO) memories are provided between interacting units in the SDP. Like the input queue between the input/output and the arithmetic units, they permit the units to work independently—while still cooperatively. The one receiving data always has a supply to work on or to store; the one providing data need not wait for the recipient to be ready. FIFOs can do this without detailed instruction from the programmer, reducing the opportunities for error in writing new application programs, and increasing the SDP's efficiency and speed.

High-capacity memories are also distributed throughout the processor. Each major unit has at least one memory. The input/output unit may typically store one million words of incoming data; the other memories together can store another million words of data in process. The arithmetic unit has one memory to store operands and results temporarily, and another to retain the microprogram repertoire containing complete instructions for complex operations such as filtering and spectrum analysis. In this, it differs from the arithmetic unit of a general-purpose computer. The index arithmetic unit's memory tells it how to sequence operations in the arithmetic unit, where series of data are stored, and what to send back to the input/output unit. Distributing memories in this way speeds retrieval: Each unit can pull data and instructions as needed from its own memory—it need not line up at a central memory awaiting its turn.

Of course, the trick in developing the SDP was to design the distributing, processing, and storage complex in such a way that no bottlenecks occur, while not being wasteful of expensive memory.

The SDP components were chosen to be not

Modular. Bell Labs Engineers Terry McPherson, left, and Paul Gloudemans check status indicators on the SDP. The top module is the SDP; the middle and bottom ones contain the input/output interfaces, the input/output memory, and the operand memory. For a given application, the SDP requires less than one-half the space of previous signal processors. Modules can be added to expand system capacity.

only fast but flexible, so the processor is reprogrammable. The same computer, therefore, can be used for other tasks that require fast processing and great memory capacity. It is already being used in several Navy applications where custom-designed equipment would otherwise have had to be developed. The resultant development cost savings, and the logistics advantage of having the same spare parts inventory for a variety of applications, are two of the attractive features of the SDP.

Quite different applications are possible. For example, the SDP could also be used to process signals from radio telescopes. Because these signals have a low signal-to-noise ratio, analysis requires the processing of a great deal of data collected over a long period of time. Millions of data from several hours may have to be stored and repetitively processed.

The SDP might also be used in telecommunications systems where large quantities of data must be processed quickly. It could be used to recognize speech and synthesize spoken answers, cancel echoes, or multiplex signals by time assignment speech interpolation. Its ability to process many signals simultaneously might be useful in a variety of applications in central offices.

Fast and able though it is, the SDP may still be improved. Its components are the generation of semiconductor devices known as LSI—large-scale integration. But Bell Labs is already studying a signal processor with VLSI—very large-scale integrated—components. The greater speed and capacity will enable the SDP to keep pace with the increasingly sophisticated processing required by, among others, the systems that listen to the sea. □

50 & 25 years ago in the RECORD

1930

Two-Way Television

Since the initial demonstration of television, both by wire and by radio at Bell Telephone Laboratories in 1927, experimental work has been steadily pursued. The latest development to be demonstrated is that of two-way television as an adjunct to the telephone.

In place of a scanning disc and set of photoelectric cells at one end for generating the television signals, and a single disc and neon lamp at the receiving end for viewing the image, there are in the two-way system two discs at each end and a bank of photoelectric cells and a neon lamp at each.

The two parties to the conversation take their places in sound-proof and light-proof booths where, sitting in front of the photoelectric cells, they look at the image of the person at the other end at the same time that the scanning beam plays over their faces.

The acoustic portion of the two-way television system is unusual in that it permits simultaneous two-way conversation without requiring either person to make any apparent use of telephone instruments. The elimination of telephone instruments is accomplished by the use of a microphone sensitive to remote sounds and a loudspeaker concealed near the television image at each station.

—H. E. Ives

A Dial PBX for Large Residences

Many families, satisfied with a single telephone not so long ago, now realize the advantages of having several.

Even more evident is a growing appreciation of adequate telephone service for very large residences and country estates, where local service between the rooms is almost as useful as central-office service. To supply the telephone needs of such residences a new dial private branch exchange has been produced.

On calls from a central office, the butler commonly answers at a small cabinet in one of the service rooms, and in one of the living rooms another cabinet may be provided at which a member of the family may answer. Local and outgoing calls require no attention, so total addition to the servants' duties is slight.

This new PBX, 740-C—comprising a cabinet for answering incoming calls, a power plant, and the necessary switch and relay equipment—serves less than 100 lines. Since it is intended for residence use, the traffic is normally much less than in a comparable business installation, and on that account fewer switches and central office trunks are sufficient.

—J. G. Ferguson

1955

The Field-Effect Transistor

The field-effect transistor, a completely new and fundamentally different type transistor, has been developed in Bell Laboratories Physical Research Department. Experimental models of this higher frequency unit are already undergoing tests in amplifiers, oscillators, and frequency and amplitude modulation circuits.

Although it operates on a principle quite different from that of the point-of-contact or junction type, it is capable of performing many of the same functions, such as amplification or oscillation, and it has the advantages of small size and low power consumption common to the others. The development of the field-effect transistor is in an early stage; however, it has already been shown that it behaves as predicted by theory and, in particular, that it should eventually be capable of operating at appreciably higher frequencies than can the point-contact or usual junction type.

Although the field-effect transistor is one of the most recent of the transistor family to be made into a practical amplifier, the underlying principle is quite old as transistors go.

It would appear that [the field-effect transistor] would find its main applications where considerations of size, weight, and power consumption dictate the use of a transistor, and where the required frequency response is higher than could be achieved with a simple junction transistor. *—I. M. Ross*

Efficiency of Bell Solar Battery Almost Doubled

The efficiency of the Bell Solar Battery has been practically doubled since its announcement by Bell Telephone Laboratories just a year ago. The battery is man's first successful device for converting sunlight directly into useful amounts of electricity.

Bell scientists, who had already achieved 6 percent efficiency when the battery was first shown, have since steadily increased its efficiency until today they have experimentally obtained 11 percent.

The increased efficiency of the battery has been achieved primarily by refinements in the fabrication process, aimed at reducing internal losses in the individual cells.

Reflex Klystrons for Microwave Radio Relay Systems

Microwave radio relay has grown remarkably in recent years, thereby creating a need for improved microwave energy sources. Of these sources, reflex klystrons are perhaps the most commonly used and Bell Laboratories has maintained a continuous effort toward developing new designs and improving existing ones. Typical of post-war reflex klystron designs, the 419A is slated for service in the TD-2 radio relay system while the 431A has helped in the realization of the objectives of the TE system. *—E. D. Reed*

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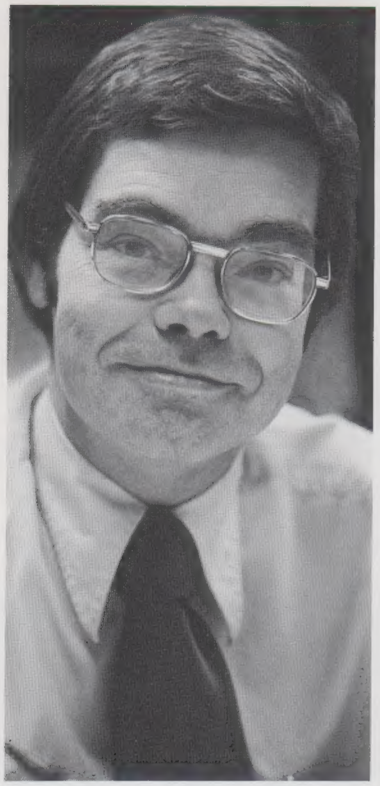

Fetz

Bruce H. Fetz (coauthor, *Tipping the scales for No. 4 ESS*) is supervisor of the Modernization and Replacement Studies Group at Bell Labs, Holmdel, N. J. This group conducts toll consolidation and toll switching replacement studies and prepares methods for Operating Companies planning for the stored-program-controlled network.

Prior to joining Bell Labs, Mr. Fetz was an aeronautical engineer with Cornell Aeronautical Laboratory in New York. He joined Bell Labs in 1969 as a member of the Toll Switching Systems Studies Department, where he worked on toll demand forecasting, mathematical models of toll demand, network effects of multiple toll switching systems, and toll switching replacement studies. He transferred to AT&T in 1975 as supervisor of Network Design with responsibility for trunk forecasting methods.

Mr. Fetz returned to Bell Labs in 1977, and in 1978 he assumed his present position.

Mr. Fetz received the B.S. and M.S. degrees in engineering science from Purdue University and the Ph.D. in applied mathematics from Cornell University. He is a member of Sigma Xi.

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Mrs. Moricz joined Bell Labs in the Toll Switching Systems Studies Department in 1972. She worked on toll switching replacement study methodology for metropolitan areas, development of the Toll Alternatives Studies Program, and rural area planning methodology. She joined her present group in 1978.

Mrs. Moricz received the B.S. degree in mathematics from Indiana University of Pennsylvania and the M.S. degree in statistics from Rutgers University.

Moricz

Edward A. Davis (*No. 4 ESS growth: serving increased toll switching needs*) is supervisor of the No. 4 ESS Field System Evaluation Group at Bell Labs in Naperville, Illinois. He is responsible for analyzing the performance of the No. 4 ESS, solving field problems, and participating in the design of features aimed at improving its performance.

Upon joining Bell Labs in 1968, Mr. Davis began designing an automatic billing circuit for No. 1 ESS. He later worked on an experimental wideband network for *PICTUREPHONE®* service signals. In 1972, he worked on the design of the Input/Output circuit for the 1A Processor.

Two years later, Mr. Davis became involved in the development of No. 4 ESS growth procedures. In 1976, he was promoted to assistant engineering manager on a rotational assignment with the AT&T Technical Policy Studies Group in Basking Ridge, N. J. In 1978, he returned to Bell Labs, supervising the No. 4 ESS System Growth and

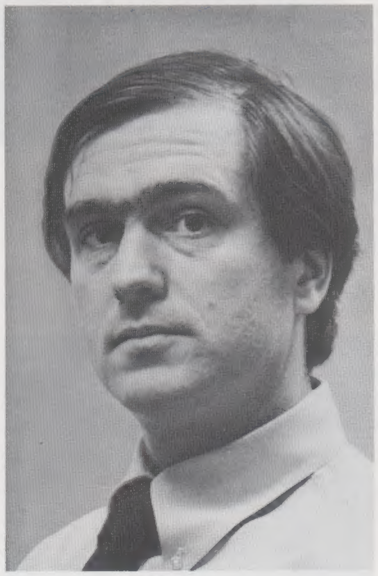
Davis

Project Coordination Group. In February of this year, Mr. Davis assumed his present position.

Mr. Davis received the B.S.E.E. degree from Michigan State University and the M.S.E.E. degree from Northwestern University. He is a member of IEEE, Tau Beta Pi, Eta Kappa Nu, Phi Eta Sigma, and Tau Sigma.

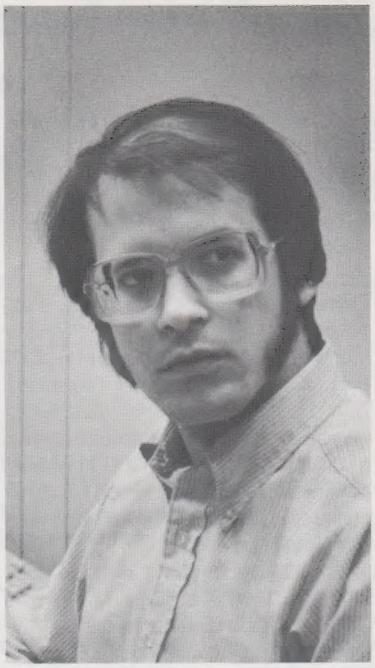
Mark R. Allyn (coauthor, *Planning for people: human factors in the design of a new service*) is staff supervisor of Residence Markets at New York Telephone in New York City. He is responsible for market research surveys of residence customers.

Mr. Allyn joined Bell Labs in 1970 as a member of the Human Factors Engineering Group, with responsibility for basic studies in display legibility and human perception of digitized speech. He also helped design customer surveys which were used to determine the acceptability of new services and new systems. In 1979, he joined New York Telephone.



Allyn

Mr. Allyn received the B.A. degree in psychology from Oakland University and the Ph.D. in psychology from Stanford University. He is a member of the American Psychological Association, the New York Academy of Science, and the American Association for the Advancement of Science.



Bauer

T. Michael Bauer (coauthor, *Planning for people: human factors in the design of a new service*) is a member of the Systems Planning Group at Bell Labs in Naperville, Ill. He is responsible for evaluation of customer performance in the first automated credit card service sites, evaluation of the service on Traffic Service Position System operator jobs, and human factors evaluation of the blind operator/TSPS console interface.

Mr. Bauer joined Bell Labs in 1977, and his initial assignment was planning and analysis of the automated credit card service field trials. In 1979, he worked on development of the File Administration System clerical interface.

Mr. Bauer received the B.S. degree in chemical engineering from Virginia Polytechnic Institute and State University, and the M.S. and Ph.D. degrees in psychology from Carnegie-Mellon University.

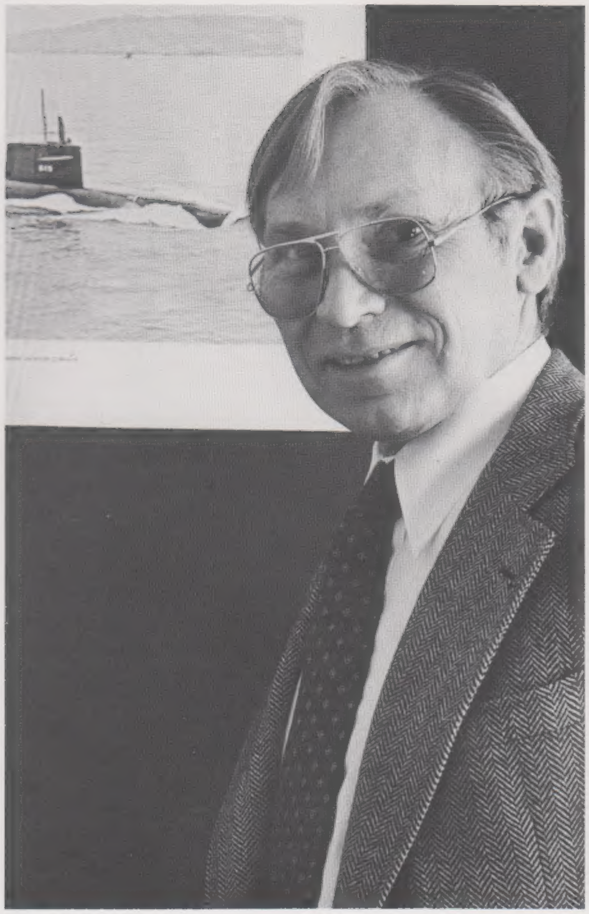
Daryl J. Eigen (coauthor, *Planning for people: human factors in the design of a new service*) is a member of the Systems Planning Group at Bell Labs in Naperville, Ill. He is responsible for developing dialing protocol plans and field trials for new stored program control network features. He is also a Bell Labs consultant for the design of a new operator console and operator job restructure.

Upon joining Bell Labs in 1973, Mr. Eigen worked for the Human Performance Technology Center. In 1975, he transferred to the Operator Systems Laboratory, where

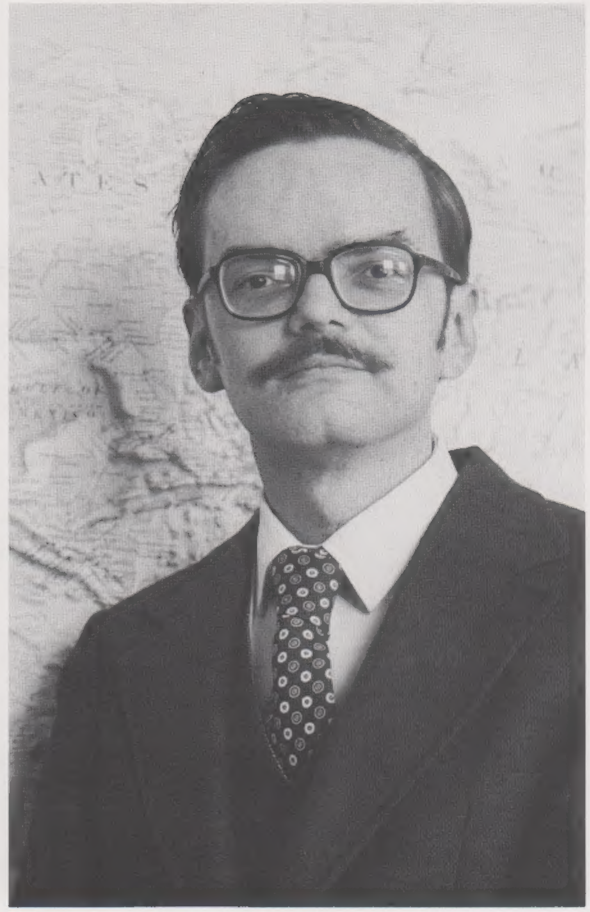
Eigen

Acronyms and abbreviations in this issue:

CUCRIT	Capital Utilization Criteria
ESS	Electronic Switching System
LSI	Large-scale integration
ODA	Office Data Assembly
PWE	Present Worth of Expenditures
SDP	Synchronous Distributed Processor
TASP	Toll Alternatives Studies Program
TSPS	Traffic Service Position System
VLSI	Very large-scale integration



Gianola



Shively

he did general systems planning and human factors work for the Traffic Service Position System. This work included writing requirements for Selective Call Screening (Charge-a-Call) and coordinating the human factors and marketing trial of the potential automated credit card service.

Mr. Eigen received the B.A. degree in psychology from the University of Wisconsin and the M.S.E.E. from Northwestern University. He is a member of the IEEE.

Umberto F. Gianola (coauthor, *Signal processor sorts sounds from the sea*) has been director of the Ocean Systems Studies Center at Bell Laboratories in Whippany, N. J., since 1971. The center is responsible for research systems engineering and applied research on advanced sonar systems for the U.S. Navy and studies of ocean acoustic phenomena.

Mr. Gianola joined the Bell Labs Communications Research Department at Murray Hill in 1953, and conducted transmission line research and applied research on digital memory devices. In 1960, he became supervisor of the Components and Solid State Devices Group, with responsibility for development of the twistor program memory for No. 1 ESS. In 1963, he became head of the Solid State Digital Devices Department, which conducted research on solid state memory devices.

In 1970, as head of the Ocean Physics Research Department, Mr. Gianola became involved in ocean acoustics analysis and experimentation.

Mr. Gianola received the B.S. degree in physics and Ph.D. degree in electron physics from the University of Birmingham, United Kingdom. He holds 37 patents and is a member of IEEE and Sigma Xi.

Richard R. Shively (coauthor, *Signal processor sorts sounds from the sea*) is supervisor of the Processor Technology Research Group at Bell Laboratories, Whippany, N. J. This group is responsible for the architecture of new digital programmable processors.

Prior to joining the Bell System, Mr. Shively helped design large scientific computers for IBM. He came to Bell Labs in 1963, and initially participated in the design of the NIKE/SAFEGUARD central processor. He designed the first realization of a fast Fourier processor, and the Synchronous Distributed Processor, a programmable signal processor now used by the Navy.

Mr. Shively received the B.S.E.E., M.S.E.E., and Ph.D. in electrical engineering from the University of Illinois. He is a member of Eta Kappa Nu, Tau Beta Pi, Pi Mu Epsilon, Sigma Xi, and the IEEE.

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